Precision Measurement of Longitudinal and Transverse Response Functions of Quasi-Elastic Electron Scattering in the Momentum Transfer Range $0.55GeV/c \leq |\vec{q}| \leq 0.9GeV/c$

2012 Hall A Collaboration Meeting

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Work support DOE Grant: DE-FG02-94ER40844

Dec 10,2011

Outline

Physics Motivation

- The test of Coulomb Sum Rule is likely to shed light on the question of whether or not the properties of nucleons are modified in the nuclear medium.
- Coulomb Sum Rule states that the integration of the longitudinal response of a nucleus over the full range of energy excitation should be equal to the total number of protons in the nucleus.
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Quasi-elastic Scattering

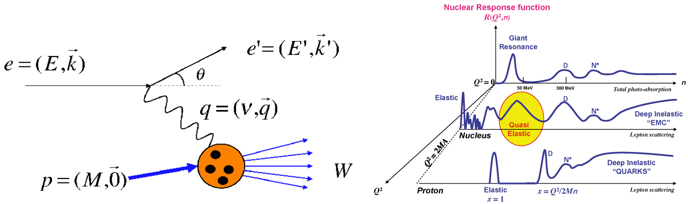


Figure: Quasi-elastic scattering

$$\frac{d^3\sigma}{d\Omega d\omega} = \sigma_M \left[\frac{Q^4}{\vec{q}^4} R_L(|\vec{q}|,\omega) + \frac{Q^2}{2\vec{q}^2} \frac{R_T(|\vec{q}|,\omega)}{\epsilon} \right]$$

where

$$\epsilon(|\vec{q}|,\omega,\theta) = \left[1 + \frac{2\vec{q}^2}{Q^2} tan^2 \frac{\theta}{2} \right]^{-1}$$

Separation of R_L and R_T and Sum Rule

$$R_L = \frac{|\vec{q}|}{Q^4 \sigma_M} \frac{1}{(\epsilon_f - \epsilon_b)} (\epsilon_f \sigma_f - \epsilon_b \sigma_b)$$

$$R_T = \frac{|\vec{q}|}{Q^2 \sigma_M} \frac{2\epsilon_f \epsilon_b}{(\epsilon_f - \epsilon_b)} (\sigma_b - \sigma_f)$$

$_f$: forward angle, $_b$: backward angle

$$S_L(\vec{q}) = \frac{1}{Z} \int_{0+}^{\infty} \frac{R_L(\vec{q}, \omega)}{\tilde{G}_E^2} d\omega$$

$$\vec{q} \to \infty, S_L \to 1$$

Data Collection

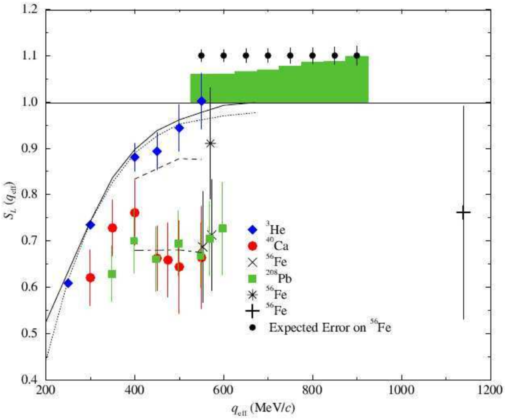
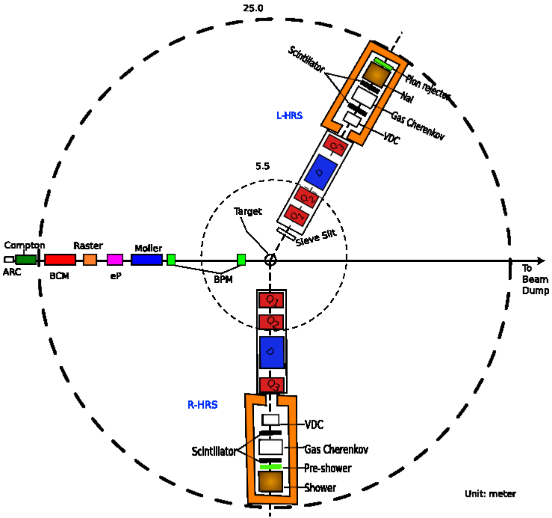


Figure: Comparison with world data. Solid black curve is the theoretical calculations for nuclear matter. The dashed curve is for ^4He. The long-dashed curve corresponds to the same calculations as the solid curve but integrated within the experimental limits of excitation energy ω

Experimental Setup



- Inclusive electron quasi-elastic scattering in Jefferson Lab
- E:0.4-4.0 GeV P_0:0.1-4 GeV θ_0:15°,60°,90°,120°
- LH_2,$LH_2 + Pb$,^4He,^{12}C,^{56}Fe,Optics
- VDC,S1,S2,Gas Cerenkov,NaI+Pion Rejector(Left),PreShower+Shower(Right)

Kinematics

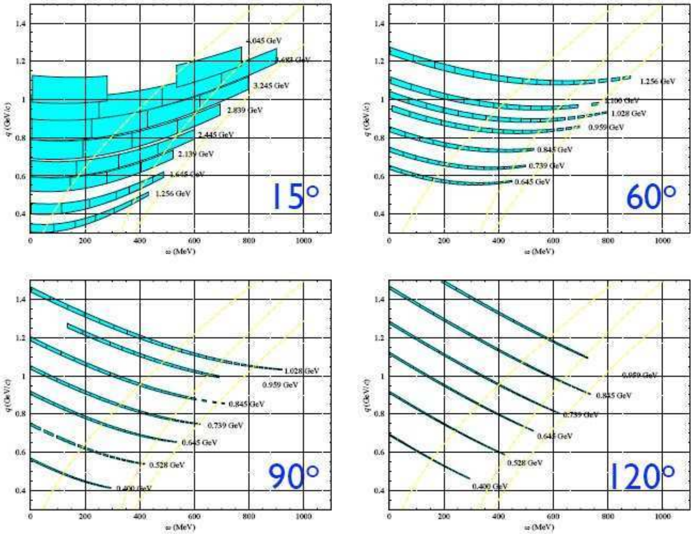


Figure: Kinematics

Gas Cerenkov Efficiency & Pion Rejection

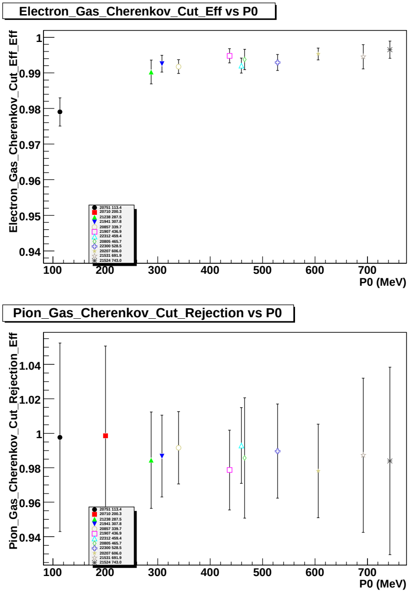


Figure: Gas Cerenkov Efficiency and Pion Rejection

Shower

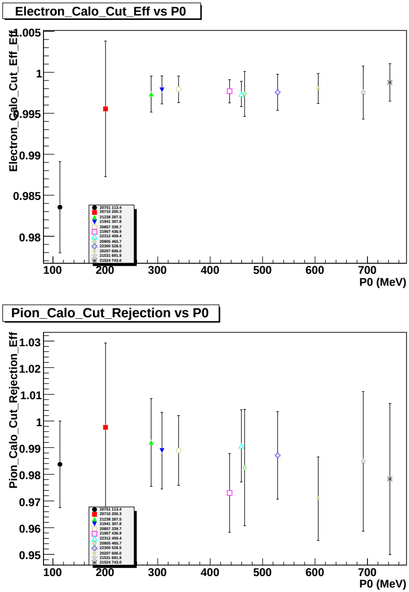


Figure: Shower and Preshower Efficiency and Pion Rejection

NaI Spectrum

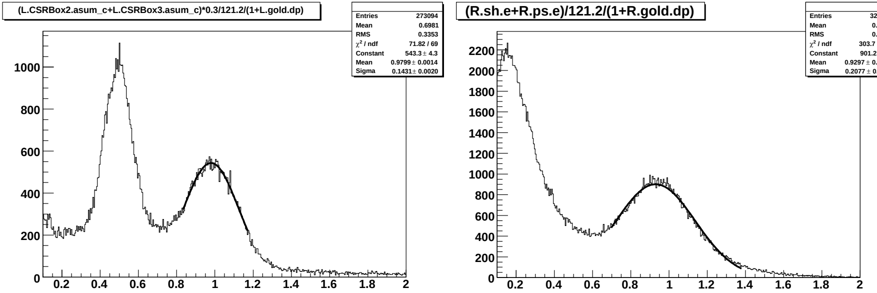


Figure: $\frac{E}{P}$ comparison between left arm NaI and right arm Shower/Preshower for same $P = 121$ MeV. Left is NaI, Right is Shower/Preshower.

Z_{react}

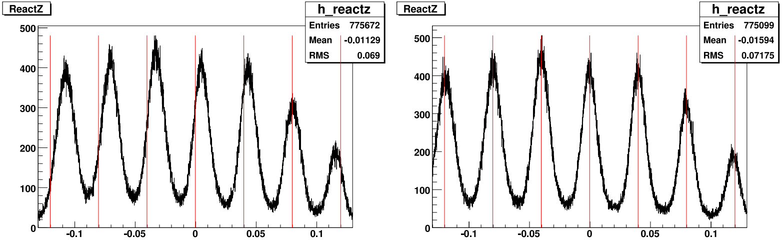


Figure: Z_{react} Optimization

Sieve Slit

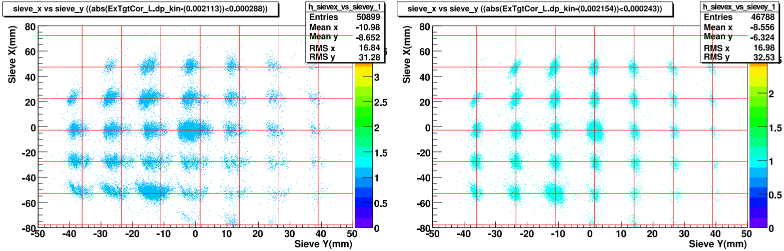
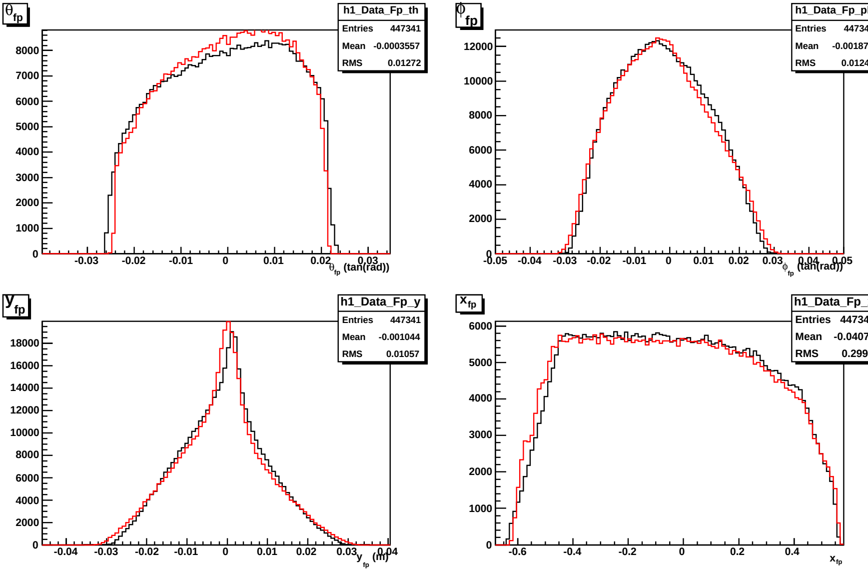


Figure: Sieve Slit Optimization

Focal plane Comparison



Target Comparison

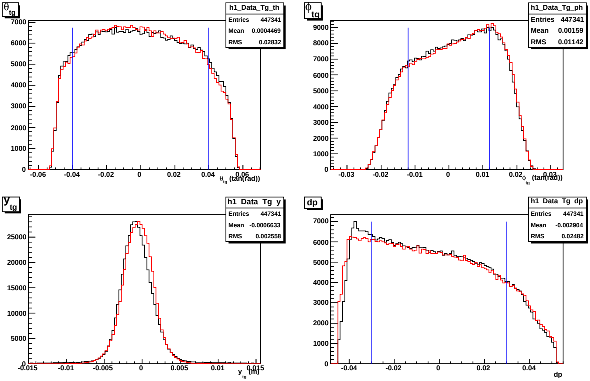


Figure: 21595 Target acceptance comparison. (Black:Data,Red:Simulation)

MC

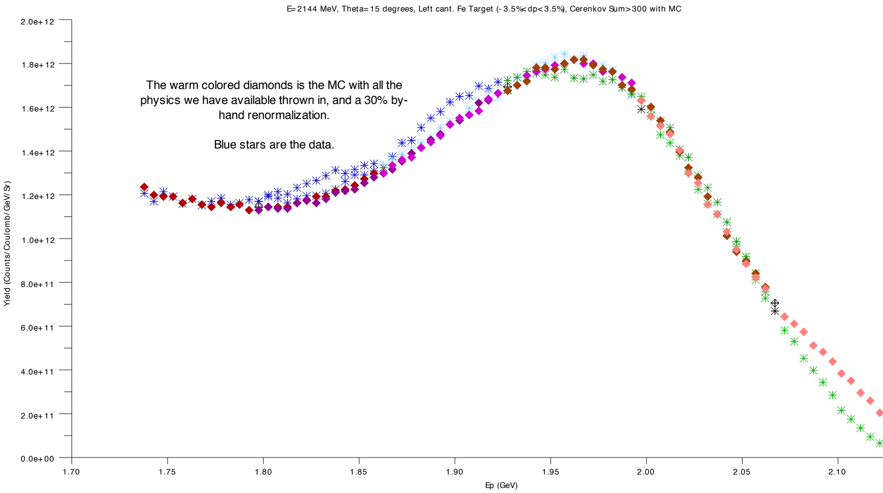


Figure: The diamonds are the MC, and the stars are the data. MC uses energy loss and multiple scattering through target and windows, and external radiation of the cross section model in the peaking approximation. MC does a good job describing the overall trend of the data. Done by Elaine.

Carbon Cross Section

θ=60°

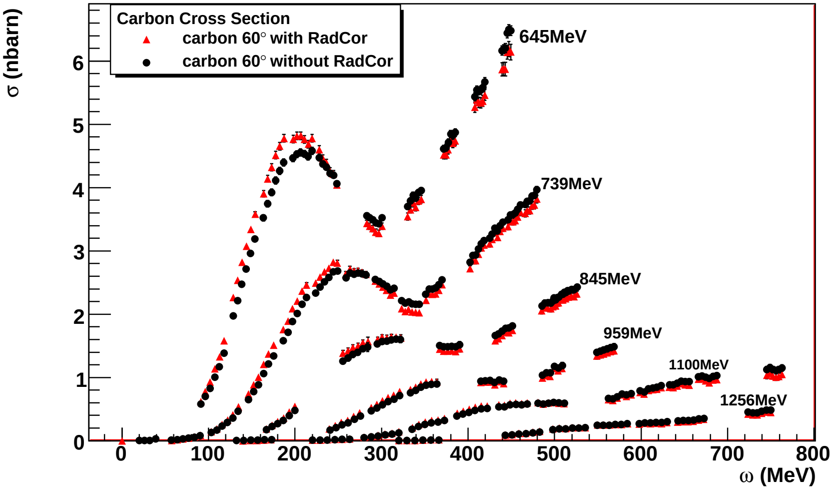


Figure: Cross section for carbon at 60°. Preliminary result

Carbon R_L

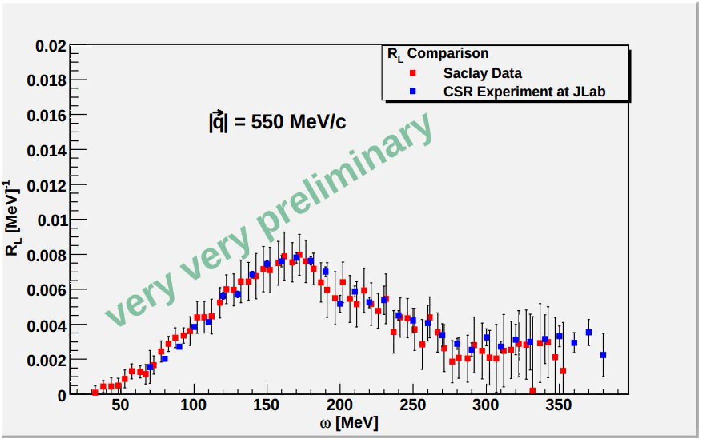


Figure: R_L at $|\vec{q}| = 550$ MeV. Preliminary result.

Fe R_L

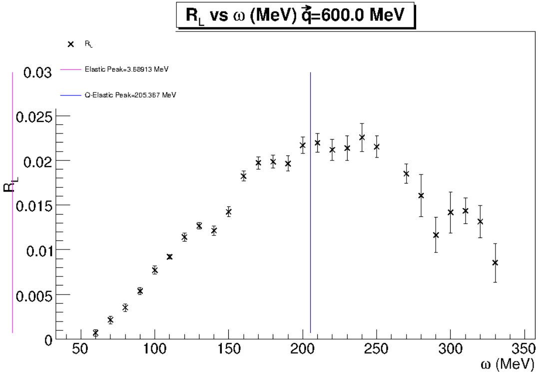


Figure: Fe R_L at $|\vec{q}| = 600$ MeV. Preliminary result.

R_L

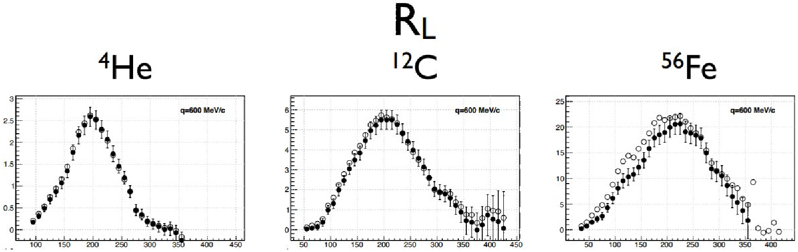


Figure: R_L at $|\vec{q}| = 600$ MeV. Preliminary result.

Collaborations

Kalyan Allada, Korand Aniol, John Arrington, Todd Averett, Herat Bandara, Werner Boeglin, **Alexandre Camsonne**, Mustafa Canan, **Jian-Ping Chen**, Wei Chen, Khem Chirapatpimol, **Seonho Choi**, Eugene Chudakov, Evaristo Cisbani, Francesco Cusanno, Raffaele De Leo, Chiranjib Dutta, Cesar Fernandez-Ramirez, Salvatore Frullani, Haiyan Gao, Franco Garibaldi, Ronald Gilman, Oleksandr Glamazdin, Brian Hahn, Ole Hansen, Douglas Higinbotham, Tim Holmstrom, Bitao Hu, Jin Huang, Florian Itard, Liyang Jiang, Xiaodong Jiang, Hoyoung Kang, Joe KatichMina Katramatou, Aidan Kelleher, Elena Khrosinkova, Gerfried Kumbartzki, John LeRose, Xiaomei Li, Richard Lindgren, Nilanga Liyanage, Joaquin Lopez Herraiz, Lagamba Luigi, Alexandre Lukhanin, Maria Martinez Perez, Dustin McNulty, **Zein-Eddine Meziani**, Robert Michaels, Miha Mihovilovic, Joseph Morgenstern, Blaine Norum, **Yoomin Oh**, Michael Olson, Makis Petratos, Milan Potokar, Xin Qian, **Yi Qiang**, **Arun Saha**, **Brad Sawatzky**, **Elaine Schulte**, Mitra Shabestari, Simon Sirca, Patricia Solvignon, **Jeongseog Song**, **Nikolaos Sparveris**, **Ramesh Subedi**, **Vincent Sulkosky**, Jose Udias, Javier Vignote, Eric Voutier,Youcai Wang, John Watson, Yunxiu Ye, **Xinhu Yan**, **Huan Yao**, Zhihong Ye, Xiaohui Zhan,Yi Zhang, Xiaochao Zheng, Lingyan Zhu

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