Study of nuclear transparency and bound nucleon form factors via tagged quasi-elastic scattering from the deuteron

K. Griffioen
College of William & Mary

Topical Workshop on Short-Range Correlations in Nuclei to Memorialize Kim Egiyan

October 20-21, 2006

Jefferson Lab, Newport News, VA USA

d(e,e'p)n Quasi-Elastic Scattering

- We have studied the reaction e + d ---> e' + p + n using CLAS to detect e' and p for E_{beam} = 5.7 GeV
- We look at all processes at high Q^2 that yield p+n alone in the final state (E6 run)
- Search for point-like configurations (PLC) of the struck proton and modifications to the proton form factor in short-range correlations (SRC)
- Reconstruct neutron recoil momenta $0<p_n<650$ MeV/c for $Q^2<6$ GeV^2 from missing momentum
- Measure proton recoil momenta $250<p_p<1000$ MeV/c for $Q^2<6$ GeV^2 in CLAS

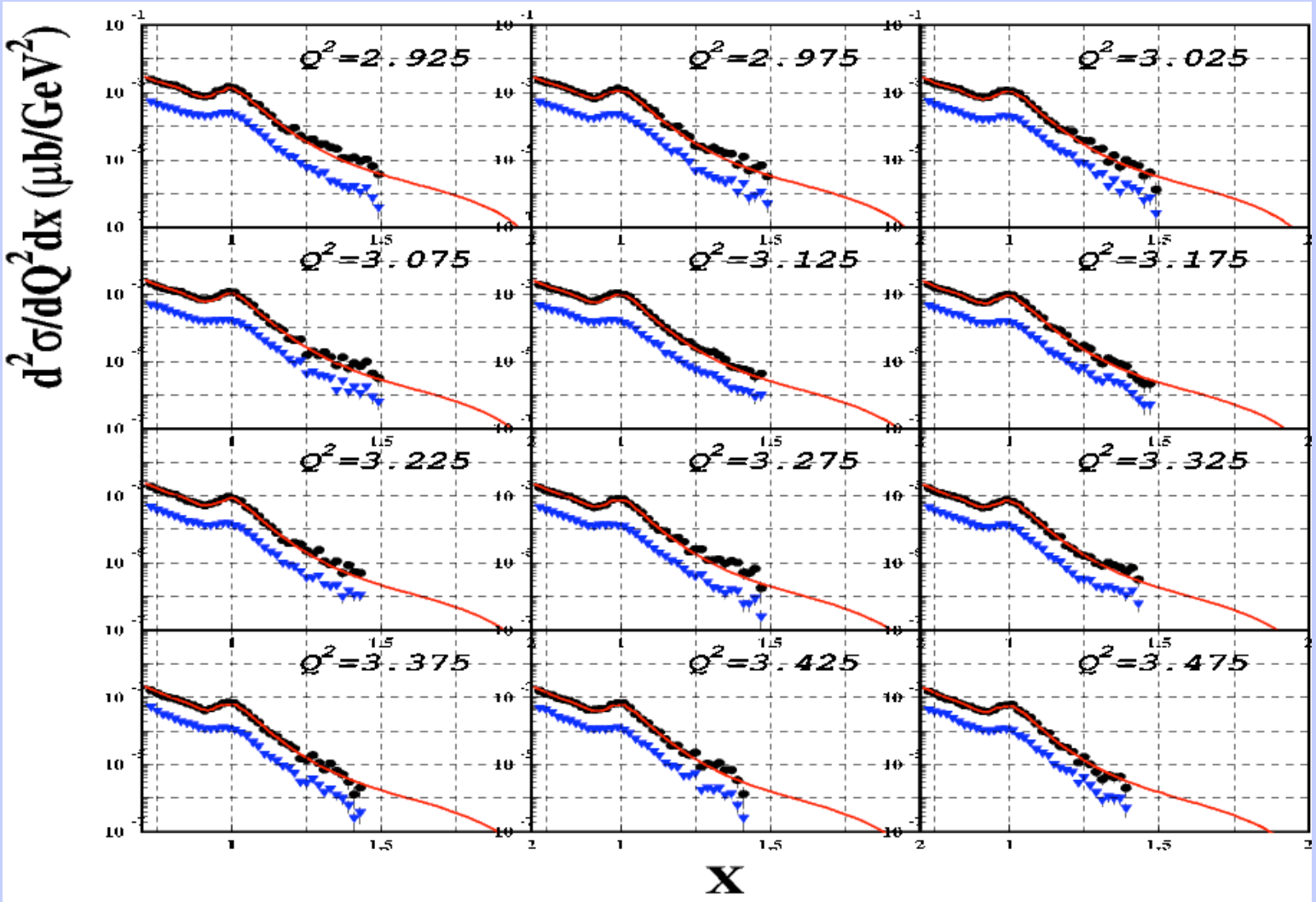
Warm-up with d(e,e’)

- Quasi-elastic scattering for $x > 1$ is sensitive to SRCs
- CLAS E6 provides (e,e’) data over a large range of x and Q^2
- Data prove consistent with best models for $x > 1$

D(e,e') with Sargsian Model

for $1.7<Q^2<6.9$ GeV^2 (data: Butuceanu)

Blue: before acceptance corrections



Variables and Cross Sections for d(e, e'p)n

$d^6\sigma/d^3E'd^3p_s$

$d^3E' \Rightarrow dx\ dQ^2\ d\phi_e$

$d^3p_s \Rightarrow dp_s\ d\theta_{\gamma s}\ d\phi_s$

Unpolarized --> one ϕ is arbitrary --> 5-fold differential

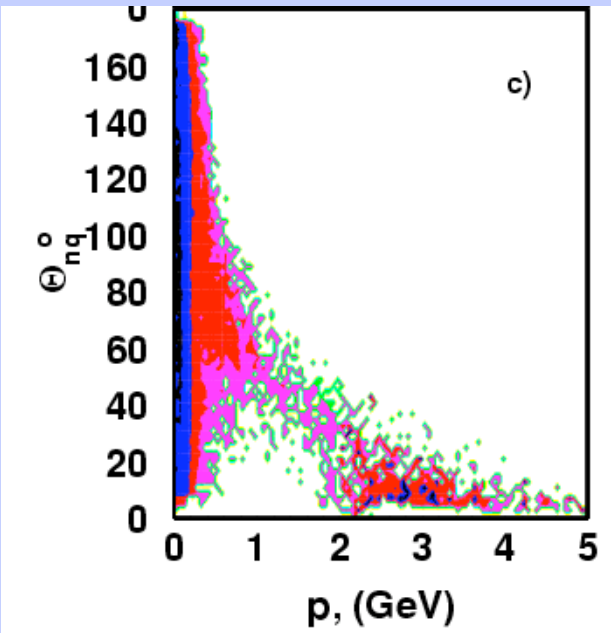
4-momentum conservation --> 4-fold differential

$(x, Q^2, \alpha_s, \phi_{\gamma s})$

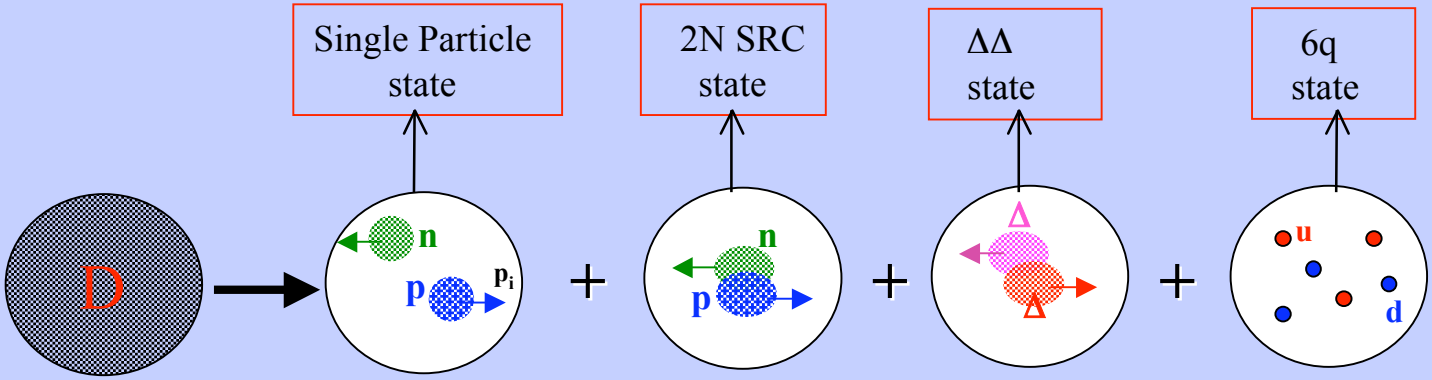
$d^6\sigma \sim P_1(\phi_e)P_2(\phi_s)P_3(x)P_4(Q^2)P_5(p_s)$

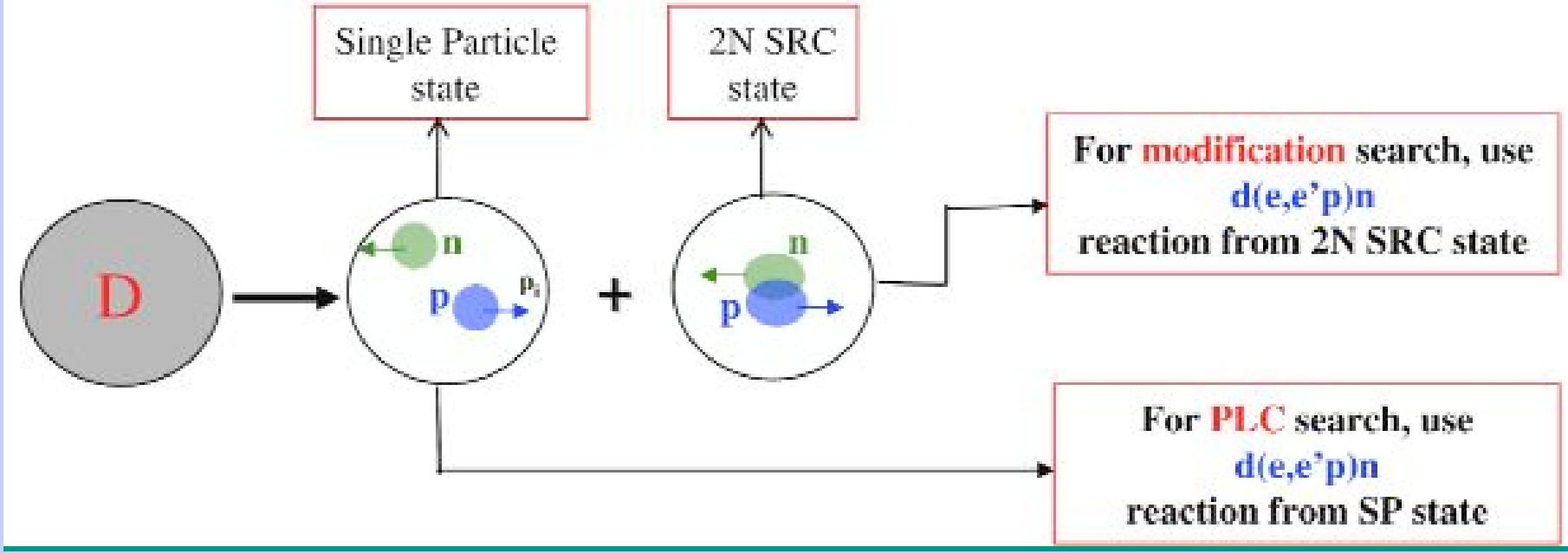
works to 10% for 6 GeV data with $\theta_{\gamma s}$ determined by 4-momentum conservation

P_1 and P_2 are uniform distributions

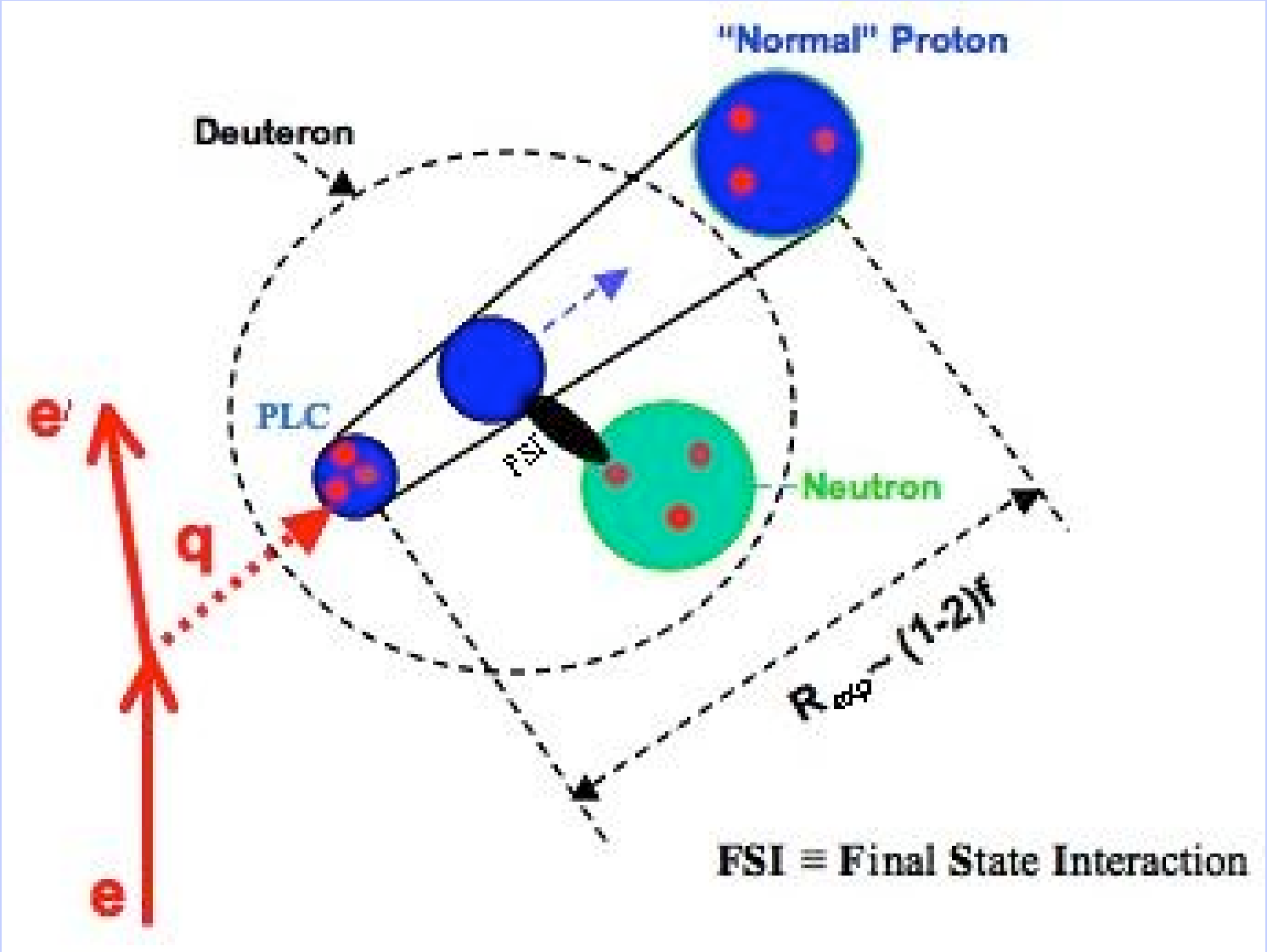


Components of the Deuteron Wavefunction





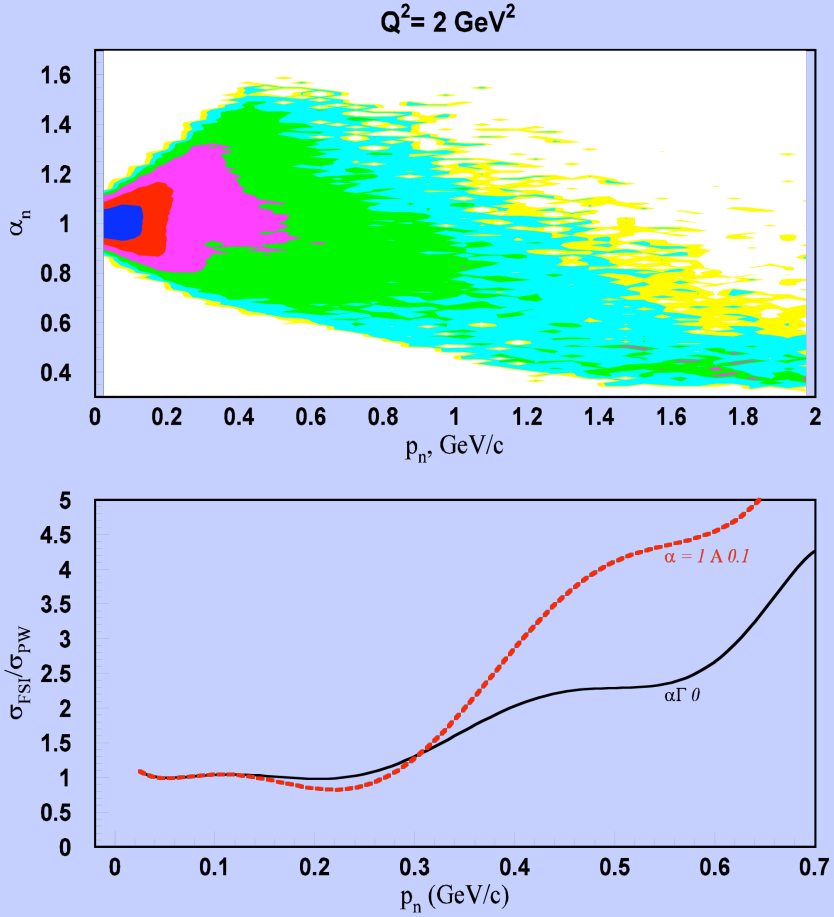
Reduced FSI of a PLC



Light-Cone Fraction α_s

- α_s = fraction of d momentum carried by spectator nucleon;
  α_s = 1: internal momentum is transverse to **q**
- Red: α_s = 1
- Black: α_s > 0
- $\sigma_{FSI}/\sigma_{PWIA}$ vs p_n
- For α_s = 1: screening for $0.2<p_n<0.3$ and double scattering for $p_n>0.3$

$$\alpha_n = \frac{E_n - p_n \cos\theta_{\gamma n}}{m_n}$$



Transparency Ratios

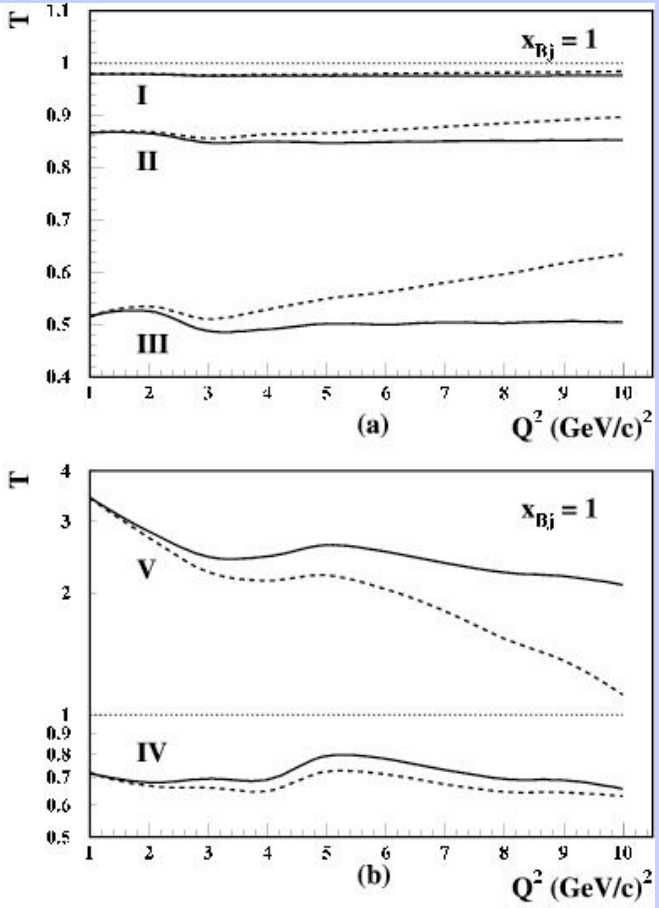
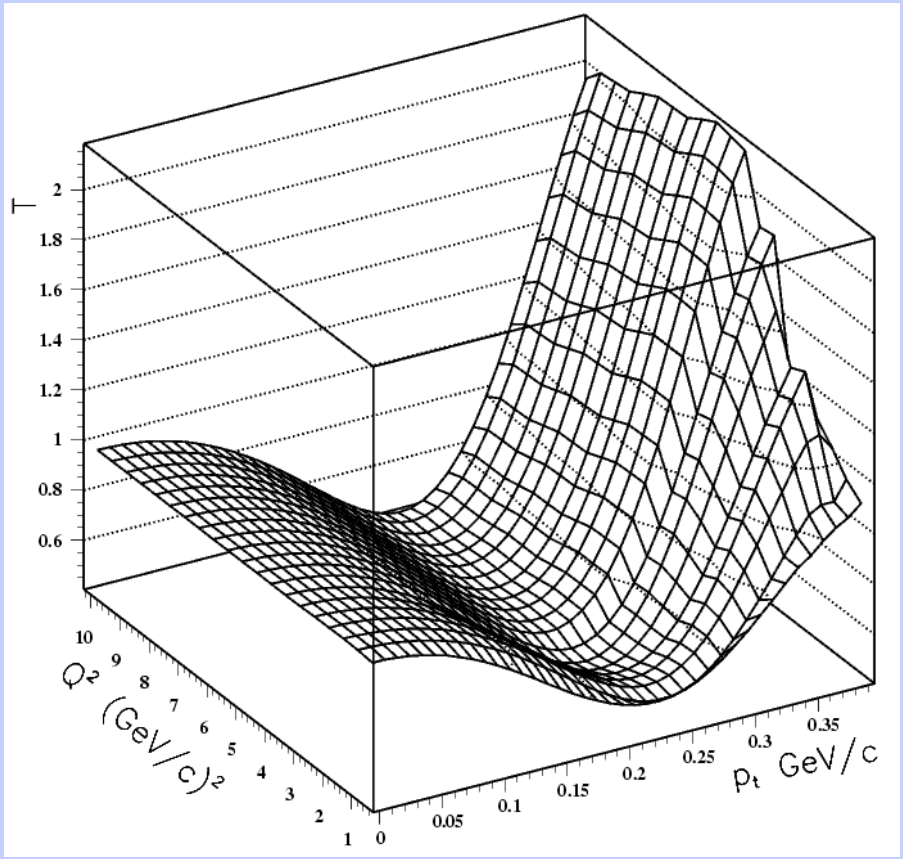


Fig.3

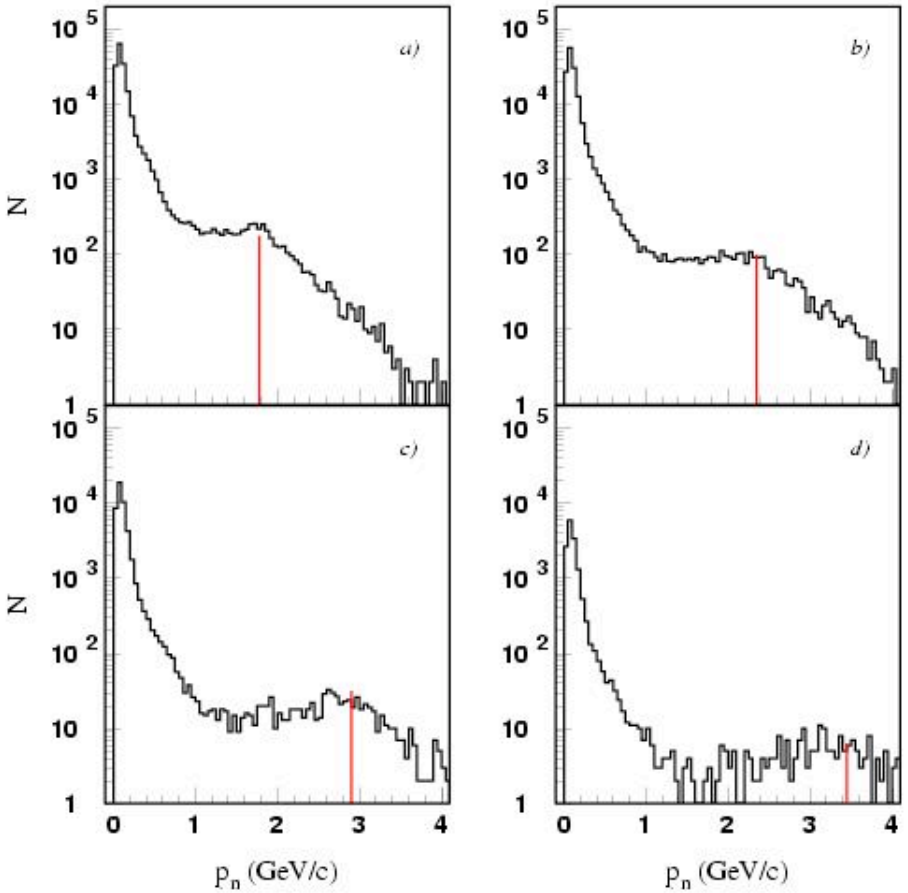


Z Phys A352(95)97
Frankfurt, Strikman, Sargsian

Left: T=exp/PWIA p_n=0, 100, 200, 300, 400 MeV/c (I-IV) w/ & w/o CT
Right: T= exp/PWIA w/o CT

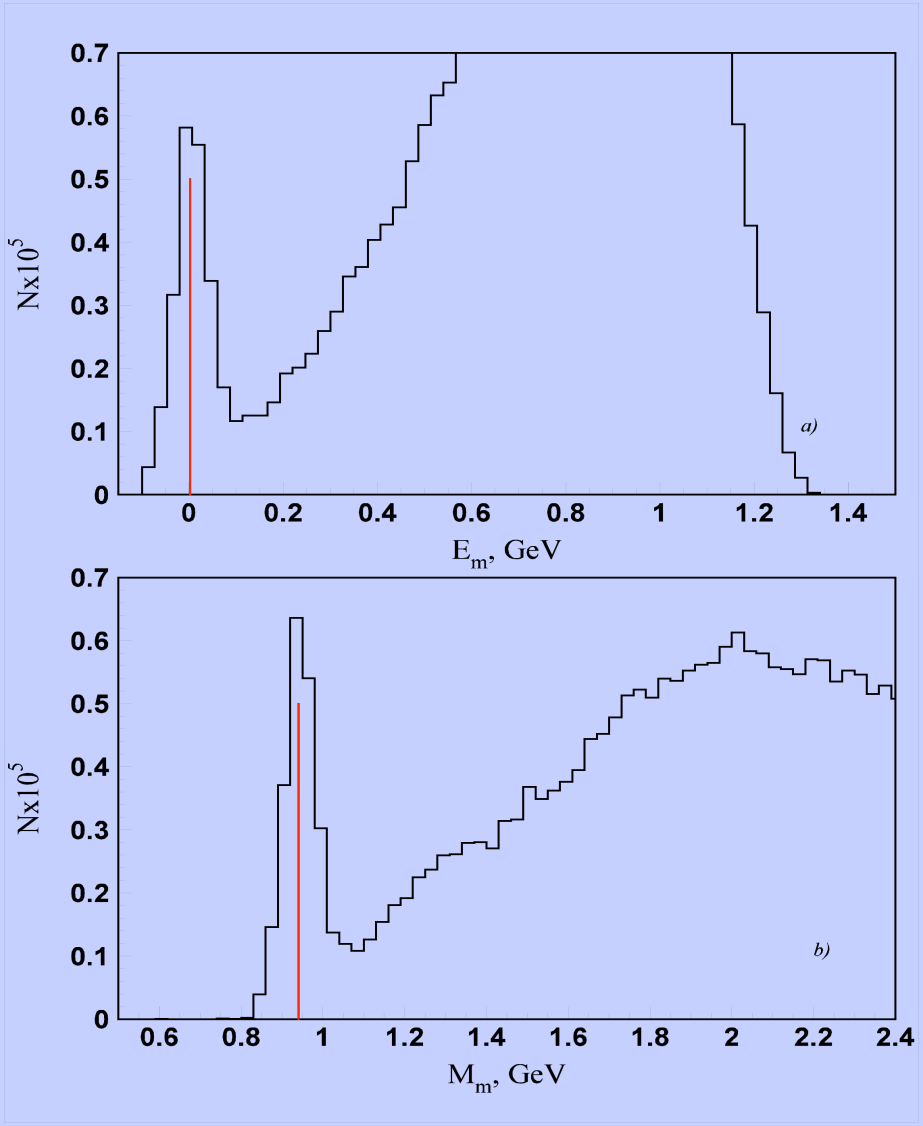
Momentum Distributions at 6 GeV

- Reconstructed p_n distributions for $Q^2 = 2, 3, 4, 5$ GeV^2 at E_{beam}=5.7 GeV (E6 CLAS)
- e n elastic (red)
- Region of interest is $p_n < 0.7$ GeV/c



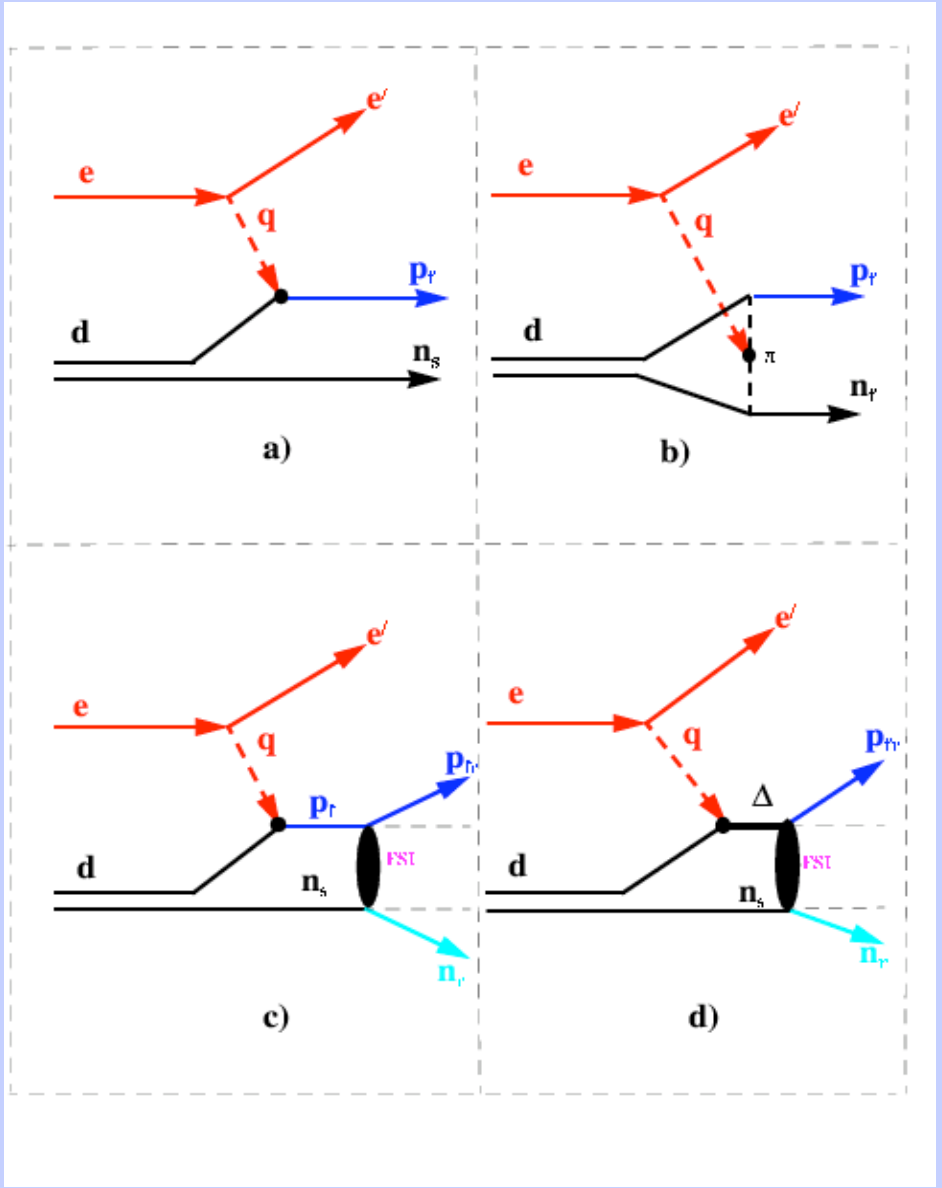
Missing Mass Technique

- E6 data with 50 MeV MM resolution
- Relatively clean separation of elastic and inelastic by fitting peak and background



Feynman Diagrams

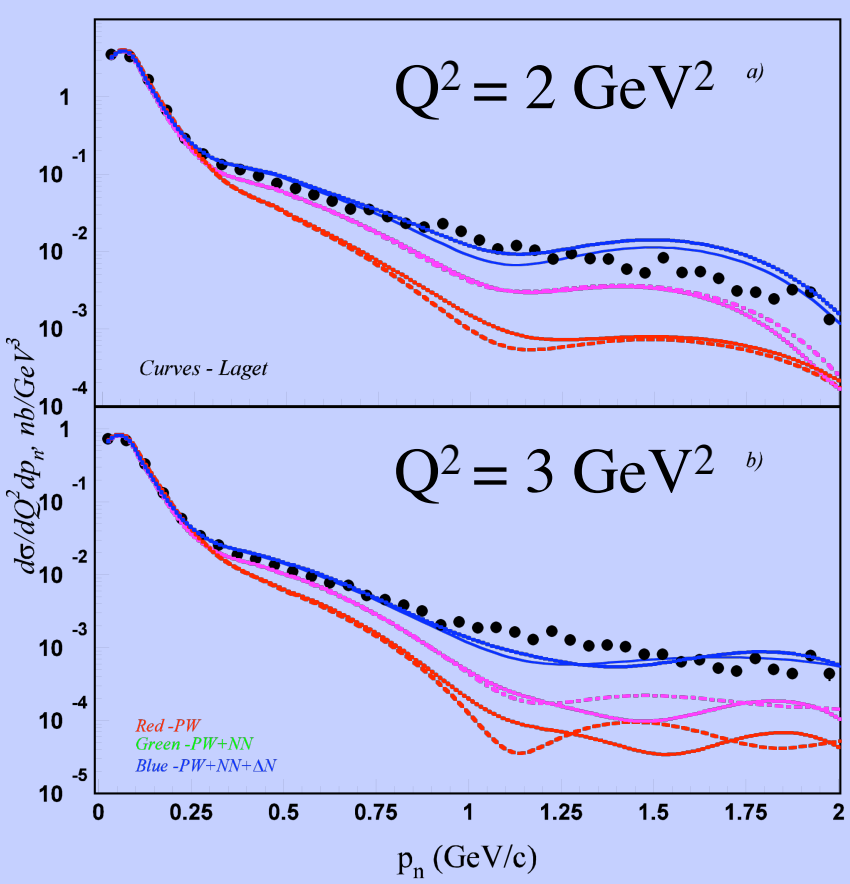
- (a) PWIA
- (b) Meson Exchange Currents (MEC)
- (c) FSI
- (d) Isobar Configuration (IC)

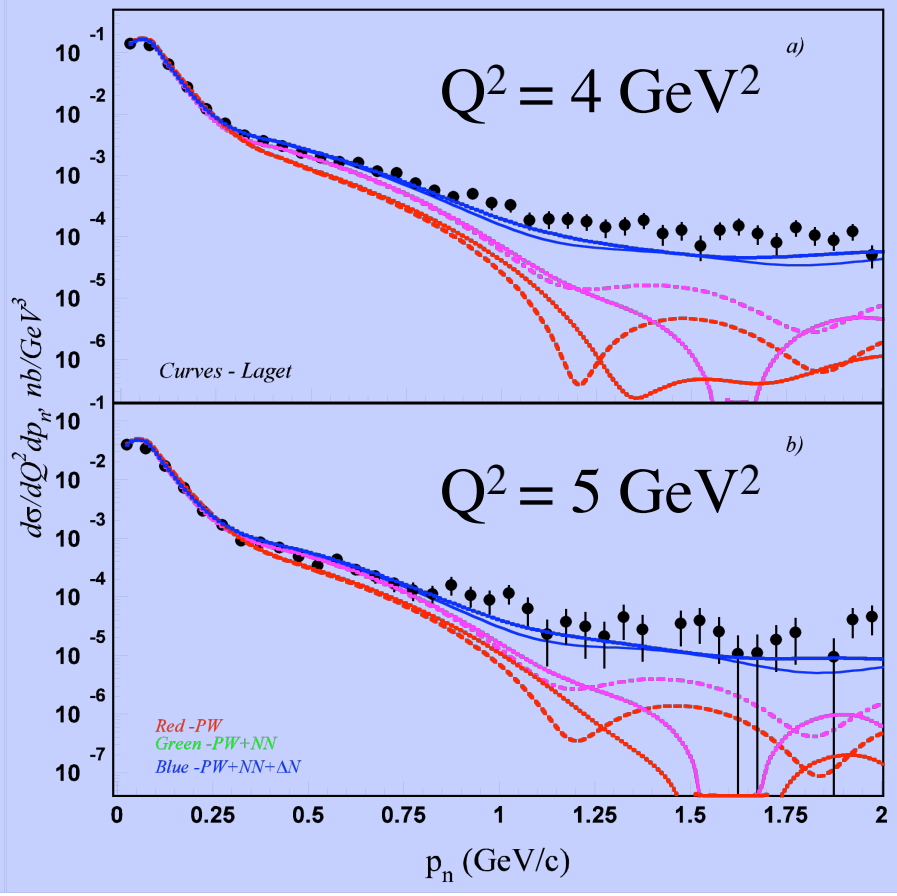


Diagrammatic Description of 6 GeV Data

- Red: PWIA
- Magenta: with FSIs
- Blue: with FSIs and IC

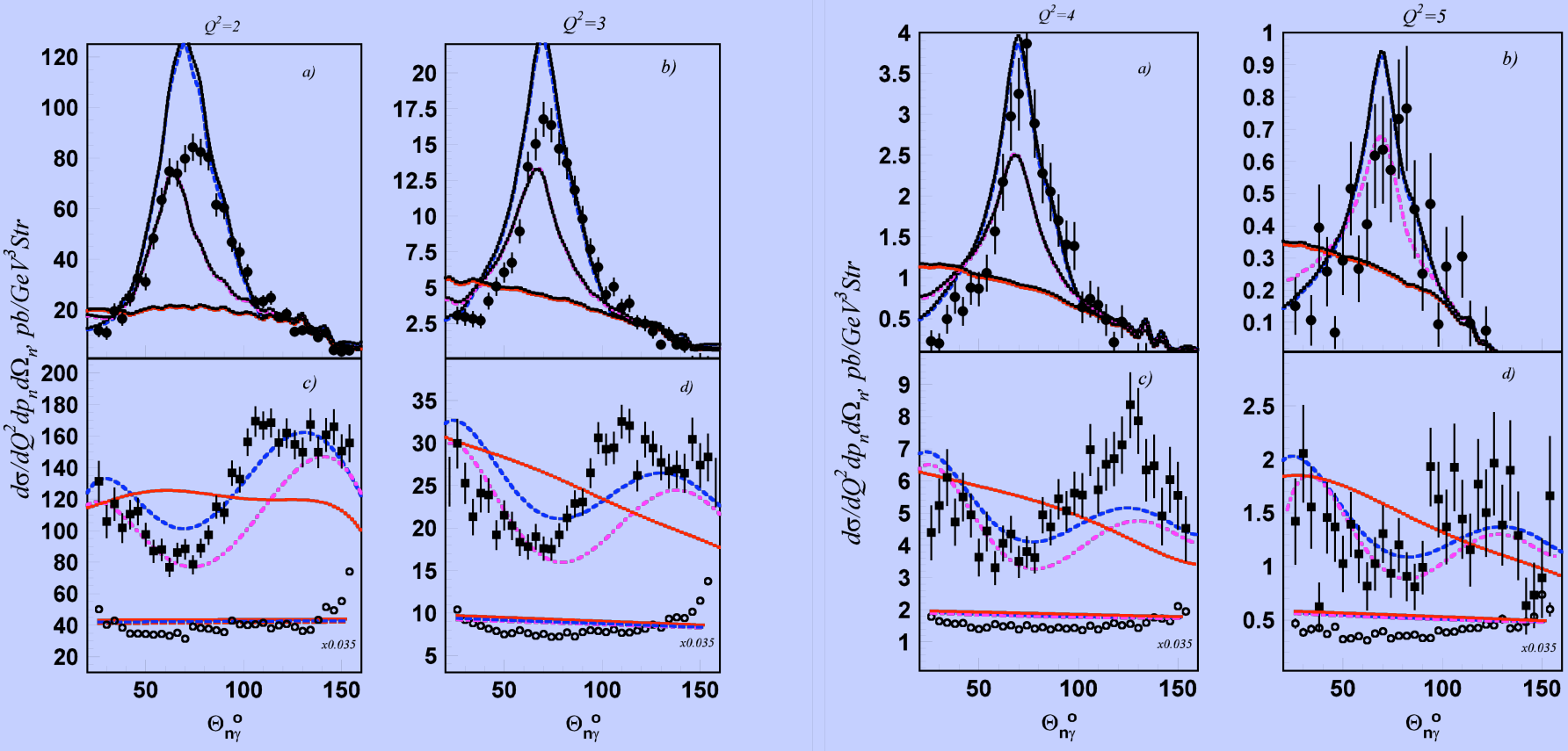
- Curves from Laget
- Generalized Eikonal Approximation (GEA) in near future to confirm this





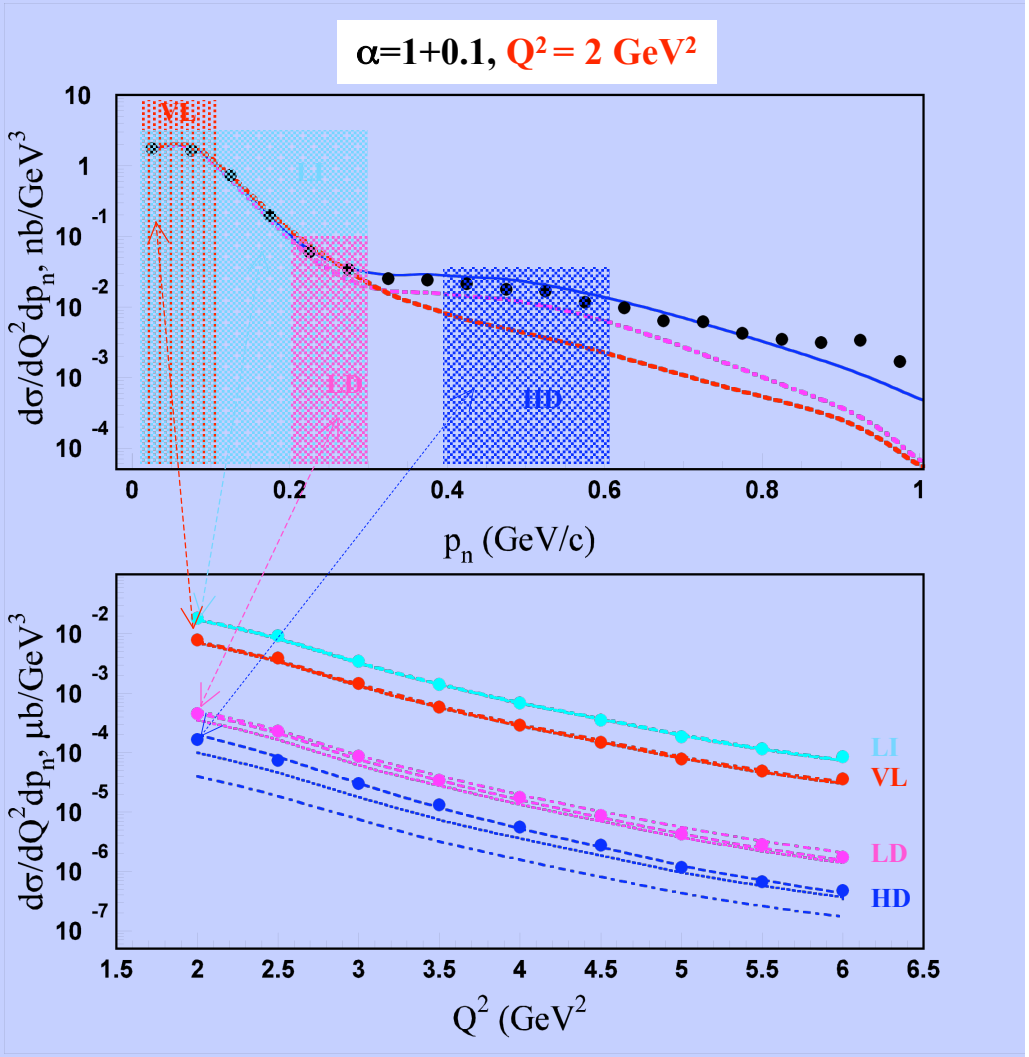
Diagrammatic Description of 6 GeV Data

- Red: PWIA
- Magenta: with FSIs
- Blue: with FSIs and IC



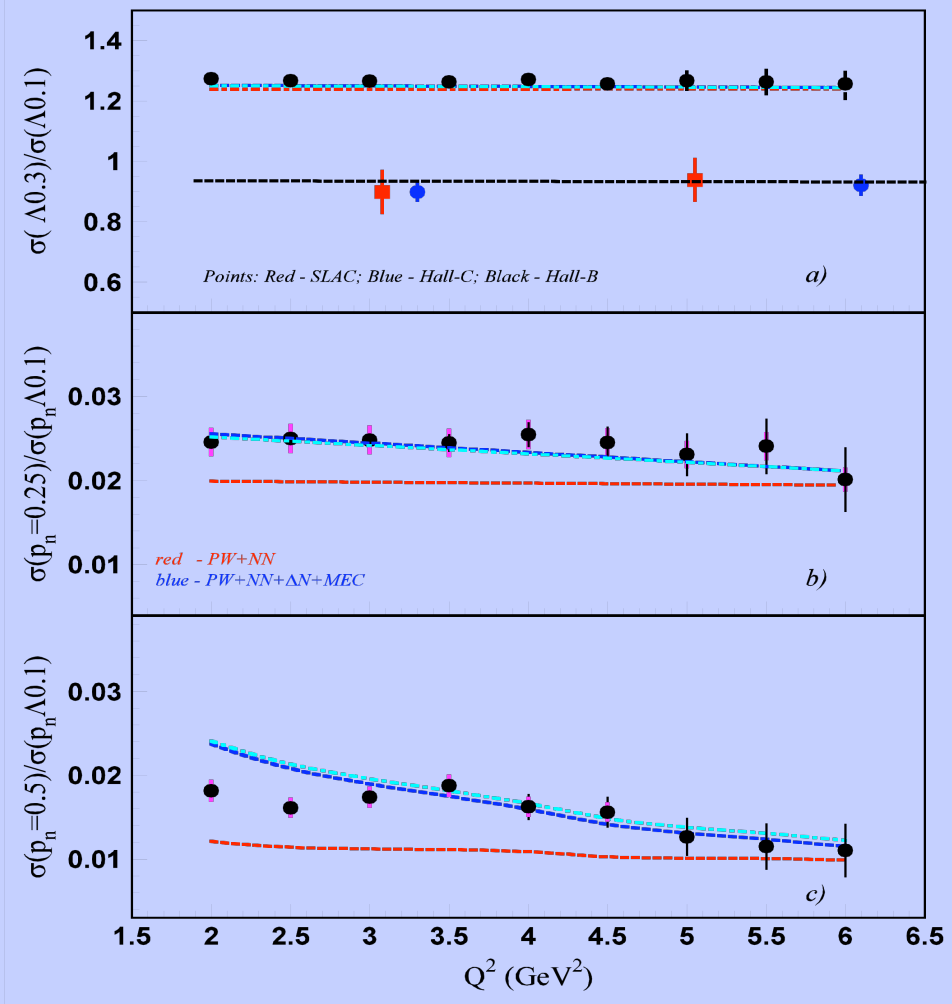
Selection of Regions in p_n

Curves are calculations:
In upper panel
Red-PWIA, **Mag. – NN**, **Blue – Full**
In bottom panel:
Dash/dot - PWIA, Dot – NN, Dash - Full



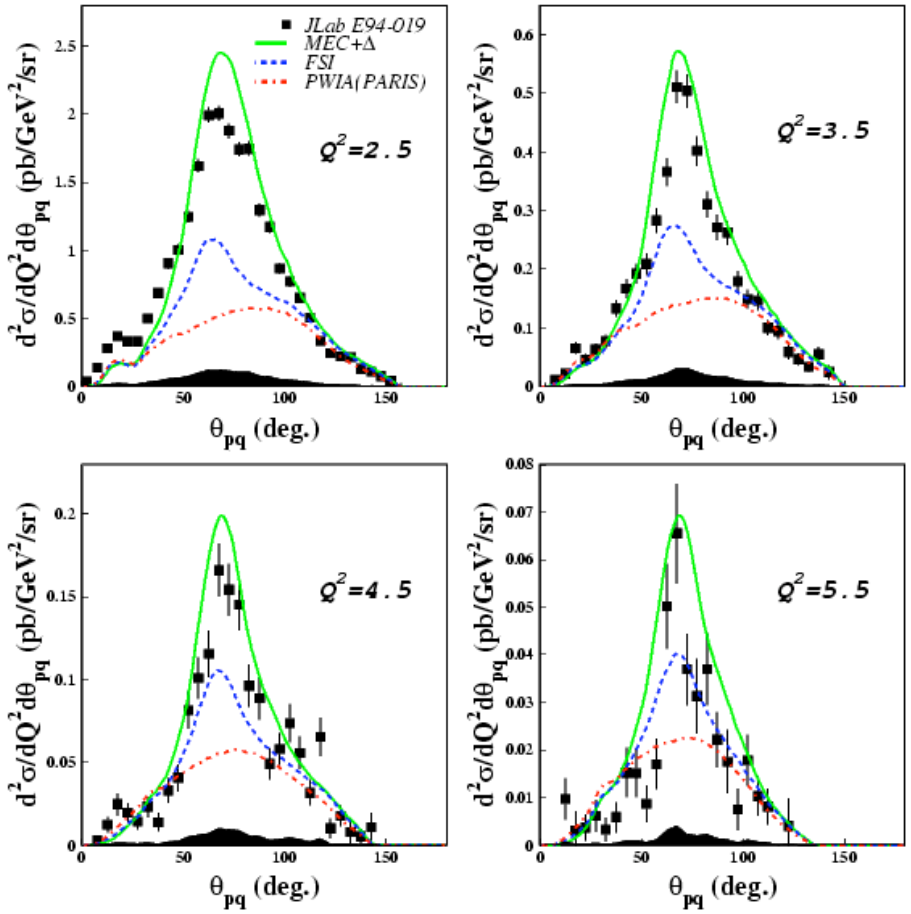
CT Results

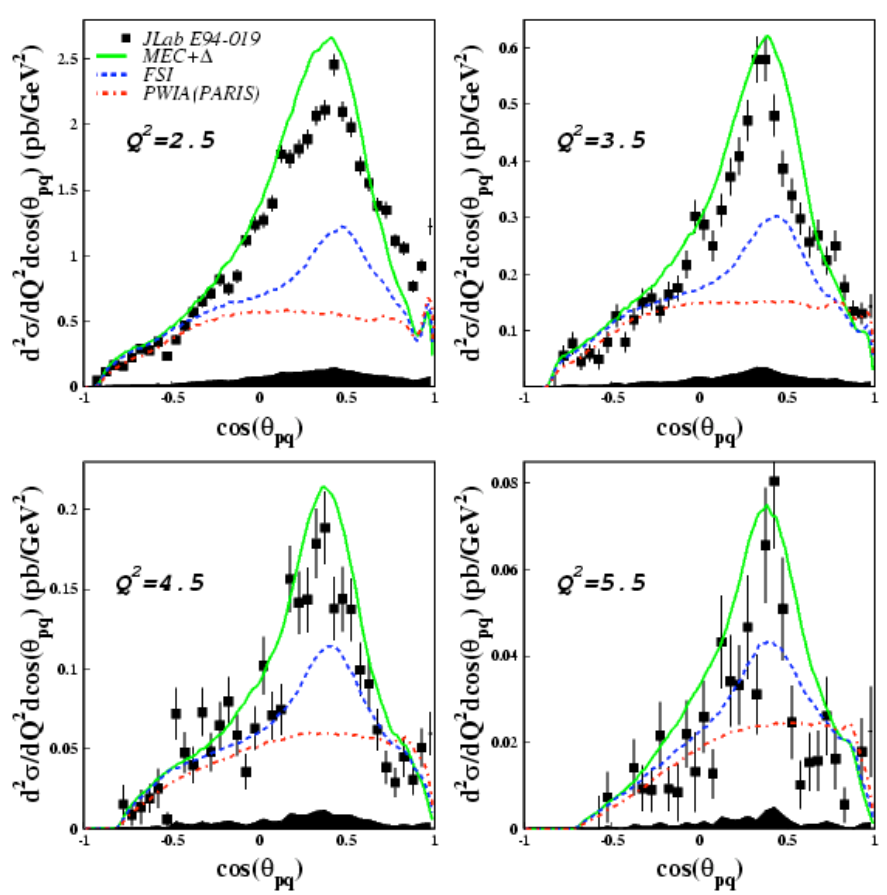
- Experimental ratios:
  $\sigma(<0.3) / \sigma(0.1)$
  $\sigma(0.25) / \sigma(0.1)$
  $\sigma(0.5) / \sigma(0.1)$
- Black points: E6
  6 GeV
- Dotted red: PWIA
- Dashed blue: Laget
  PWIA+FSI+IC
- No observed CT



D(e,e'p_s) (Butuceanu)

$\cos\theta_{pq}$, θ_{pq} : summed over x, p_s
$200 < p_s < 1000$ MeV/c

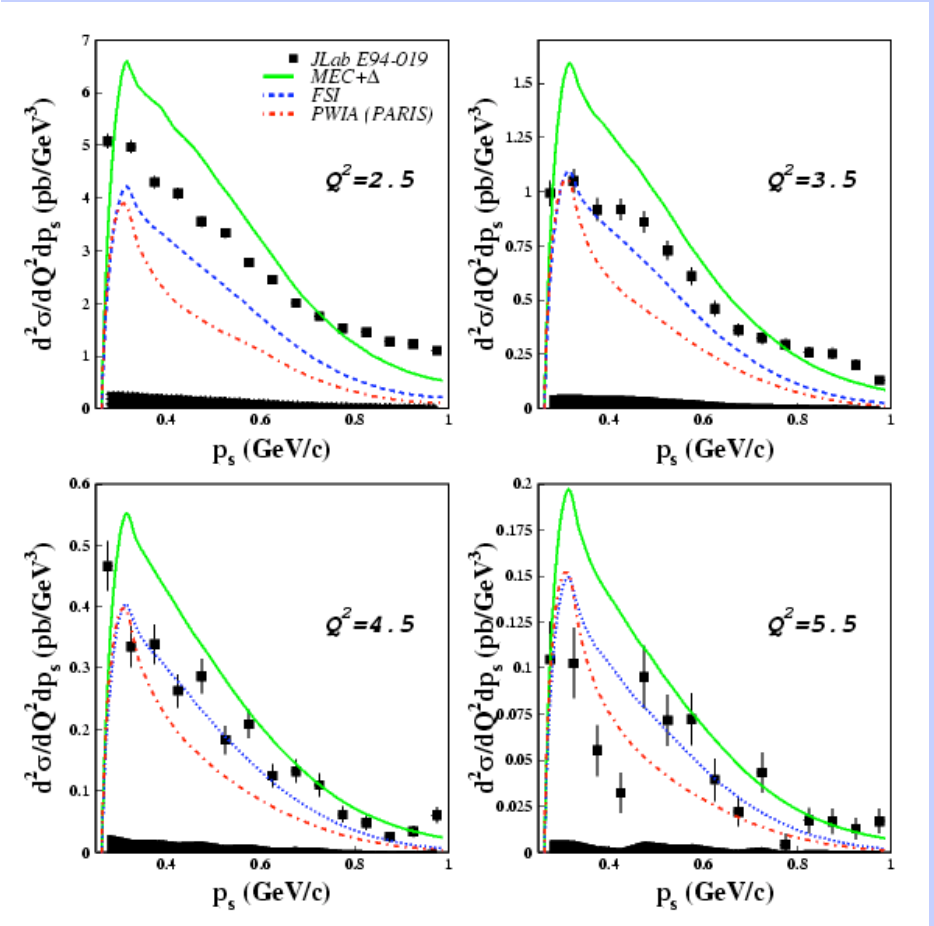


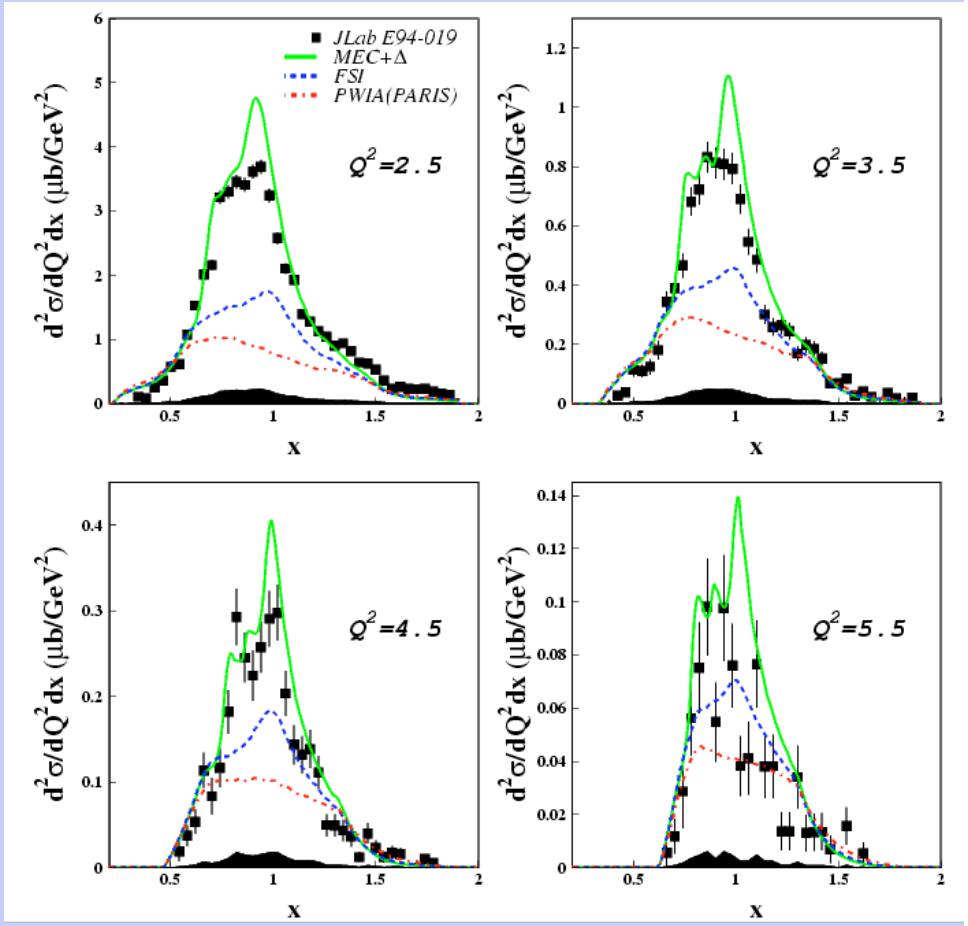


D(e,e'p_s) (Butuceanu)

p_s: summed over x, θ_{pq}

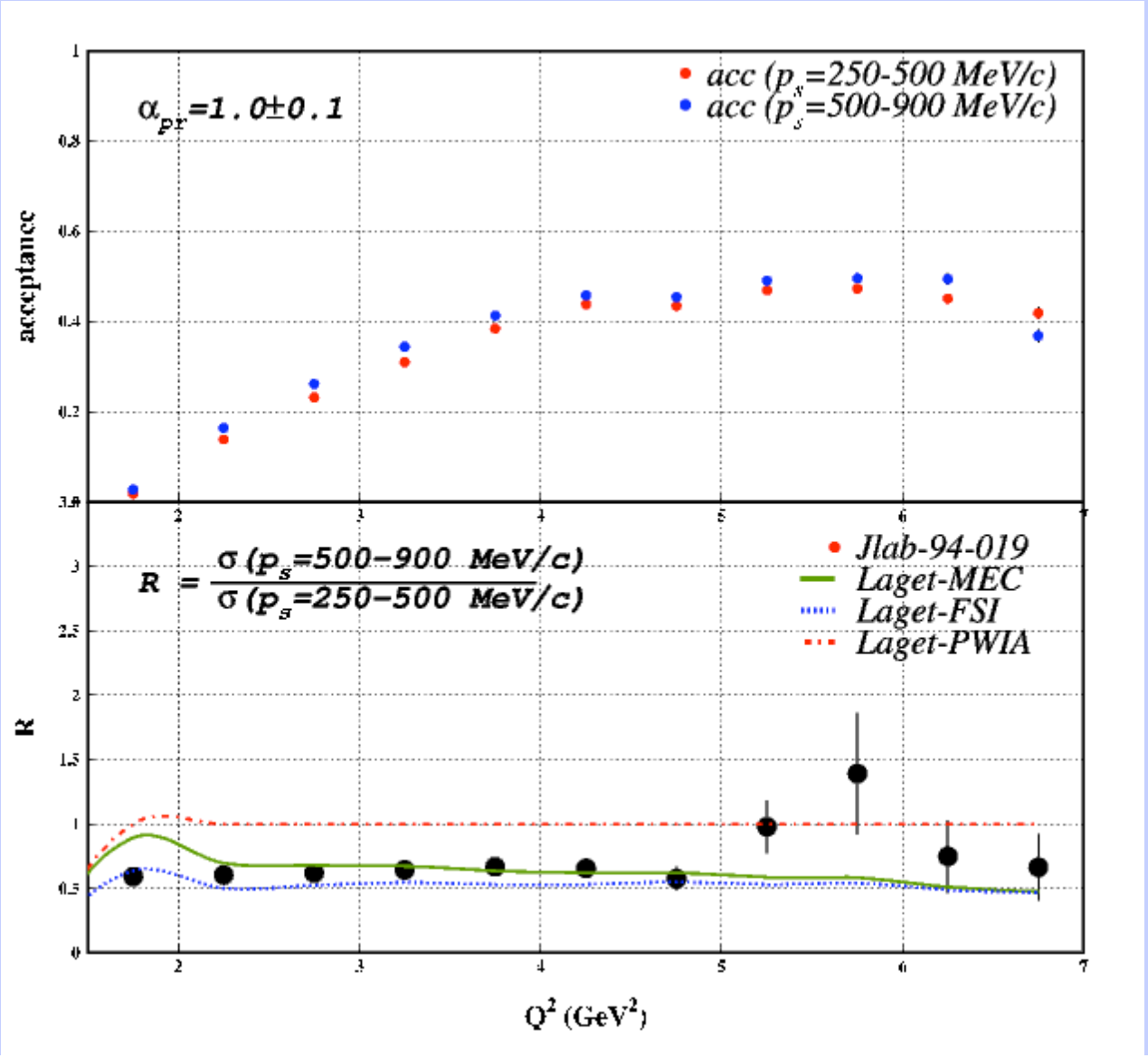
x: summed over p_s, θ_{pq}



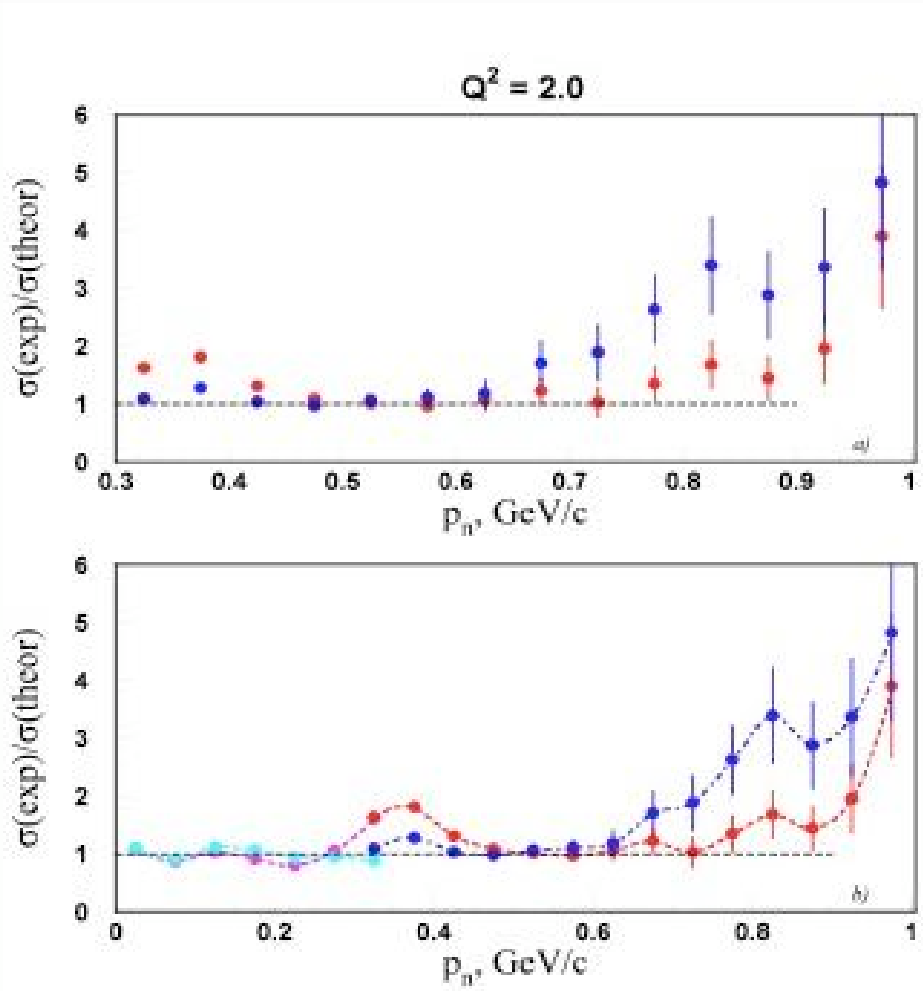


D(e,e'p_s) (Butuceanu)

Transparency Ratio



Where the FSIs Are



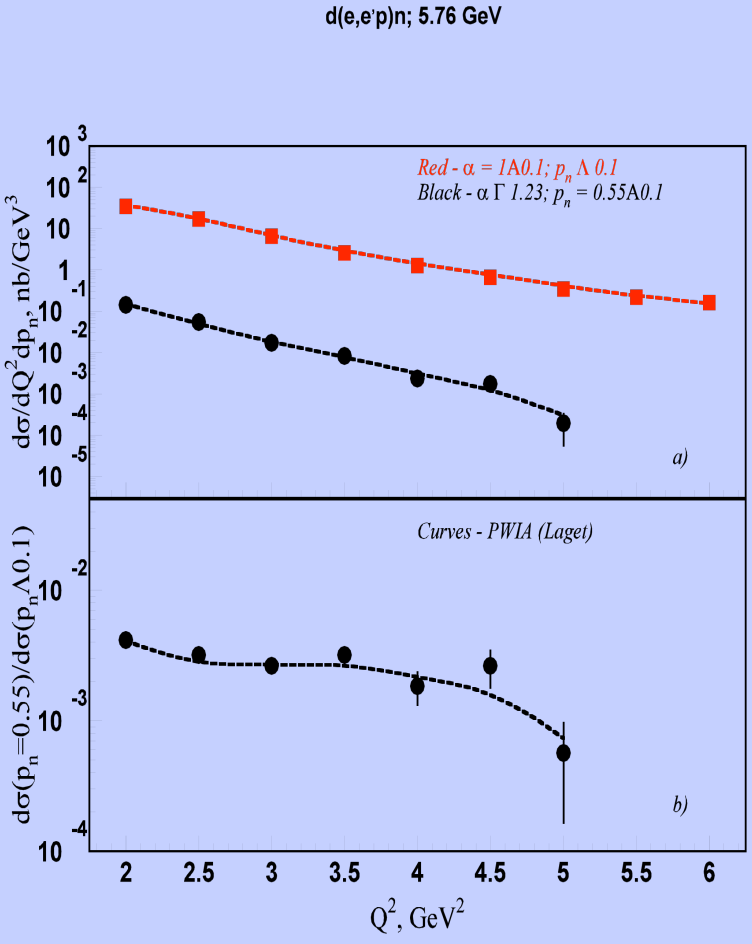
- Top: $\alpha_s > 1.23$; blue = full calculation; red = PWIA
- Bottom: $\alpha_s = 1$ (cyan) below p_n=0.3 GeV/c; same as upper curve for p_n>0.3 GeV/c
- FSI absent for p_n<0.2 GeV/c and for 0.45<p_n<0.55 GeV/c

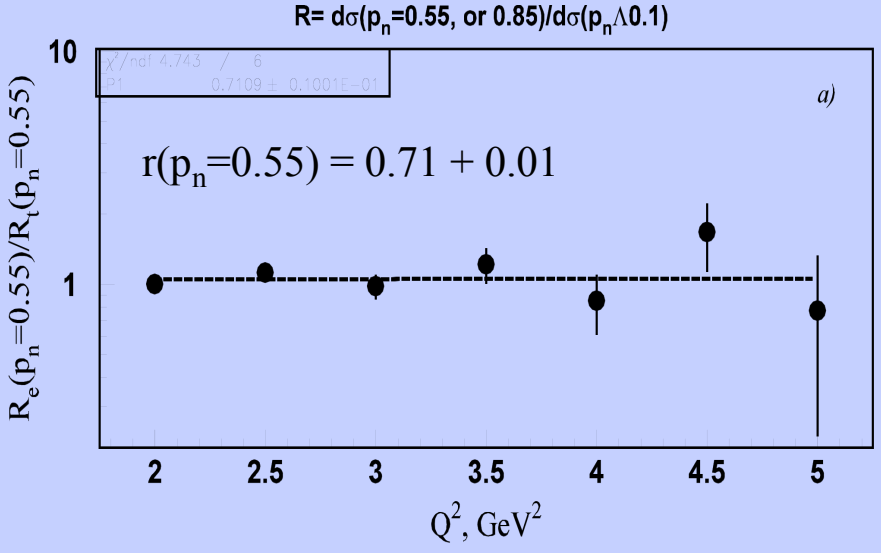
Nuclear Modification of Form Factors

- $T_{e/e}$ is the ratio for $0.45<p_n<0.65$ and $\alpha_s > 1.23$ to $p_n<0.1$ and $\alpha_s = 1$
- $T_{t/t}$ is the same ratio for PWIA

$$FF_{nm} = \frac{1}{\left(1+\frac{Q^2}{r}\right)^2}$$

$$\frac{T_{e/e}}{T_{t/t}} = \frac{1/\left(1+\frac{Q^2}{r}\right)^4}{1/\left(1+\frac{Q^2}{0.7\mathrm{GeV}^2}\right)^4}$$





Summary

- e+ d -> e' + n + p
  - simple, rigorously defined, easily measured reaction channel
  - nearly complete kinematics of a rare process at high Q^2
- Measurements
  - d(e,e') for x > 1 SRC
  - d(e,e'p) with recoiling n
  - d(e,e'p) with recoiling p
- The physics
  - No evidence for CT up to Q^2=6 GeV^2
  - No evidence for in-medium modifications of nucleon form factors up to Q^2=6 GeV^2