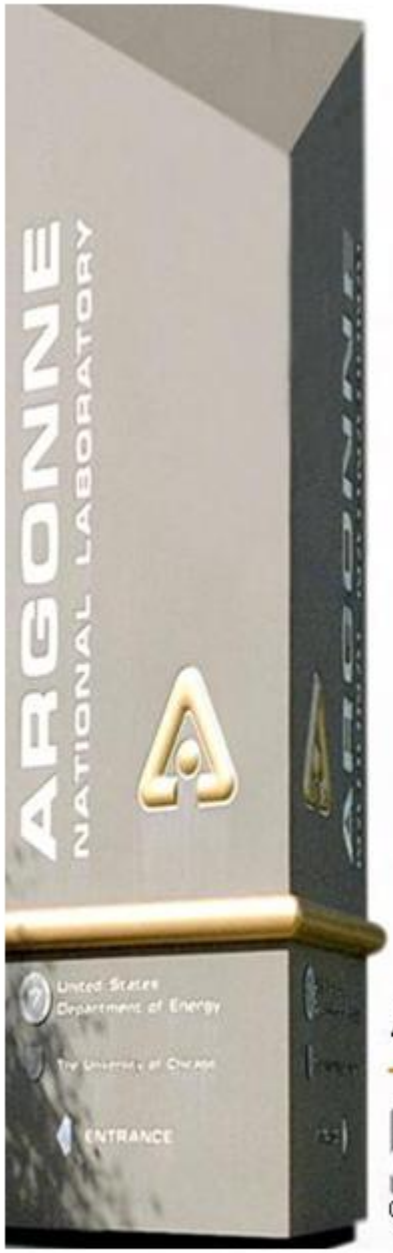

Color Transparency

PN12 Workshop, JLab

November 1-5, 2004

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Office of Science

A U.S. Department of Energy
Office of Science Laboratory
Operated by The University of Chicago

Outline

- Introduction to Color Transparency phenomenon
- Experimental Overview :
  - Quasi-free A(e,e'p),
  - Quasi-elastic A(p,2p)
  - Rescattering
  - Meson electroproduction
- 12 GeV possibilities
- Summary and outlook

Color Transparency was first introduced two decades ago by Mueller and Brodsky

CT is a spectacular prediction of QCD : Under the right conditions, the nuclear matter will allow the transmission of hadrons without attenuation. Such a phenomenon is totally unexpected in a hadronic picture of strongly interacting matter, but straightforward in quark gluon basis, this is one of the features which makes it so interesting.

Color Transparency : Basic idea

- A hadron is superposition of quark-gluon configurations of different space size

- Small spatial size configurations interact with small cross-section with target (QED : e+e- pair of a small size has a small cross-section determined by its dipole moment)

- Special hard processes have the power to isolate minimal Fock state in the hadron wave function such as the distance between the quarks is of the order of 1/Q

$\Rightarrow$ **CT follows from QCD but in a specific kinematical region**

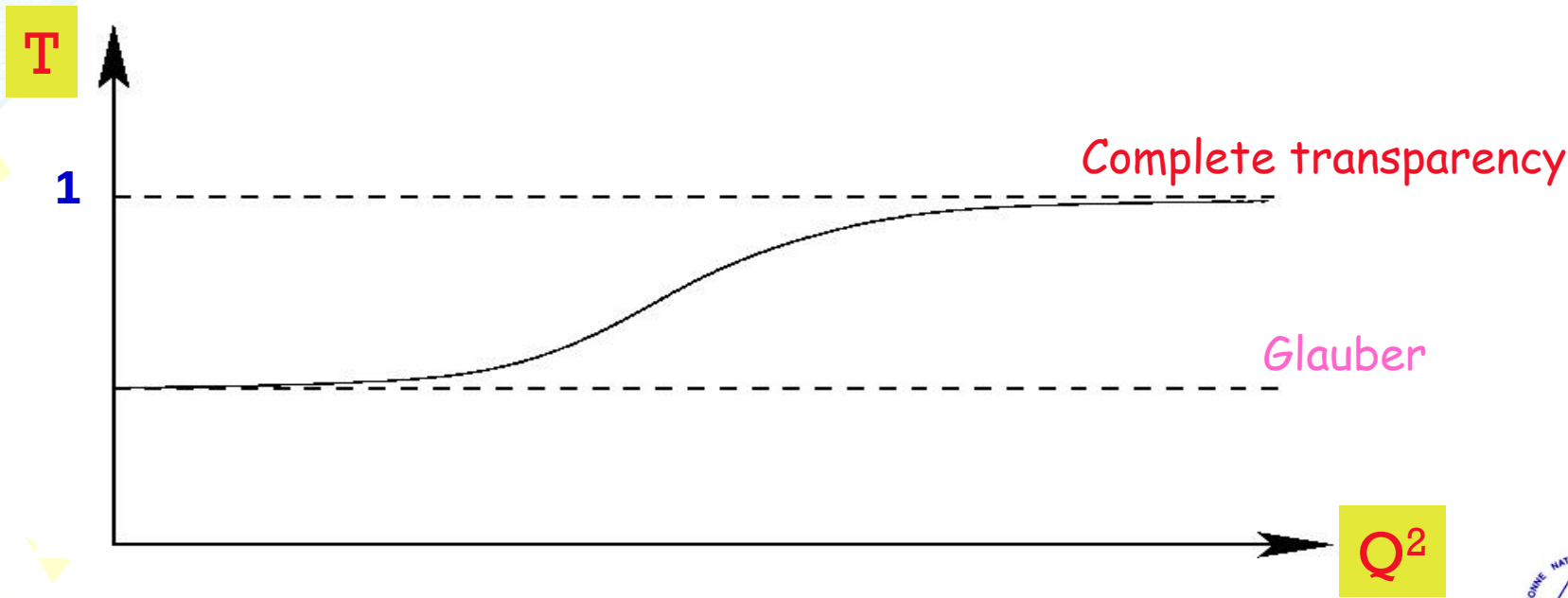
CT : Non trivial interplay between many interesting mechanisms

- CT is closely related to the dynamics of quark confinement in the hadron
- Short distance part of a minimal Fock state of the hadron wave function
- Mini-hadron evolution to its normal size
- Reduced final state interaction of the mini-hadron with spectator hadrons

Signature of Color Transparency

The signature of CT is the rising of the nuclear transparency $T(A,Q^2)$ with increasing hardness of the reaction :

$$T(A,Q^2) = \sigma_A / A\sigma_N$$



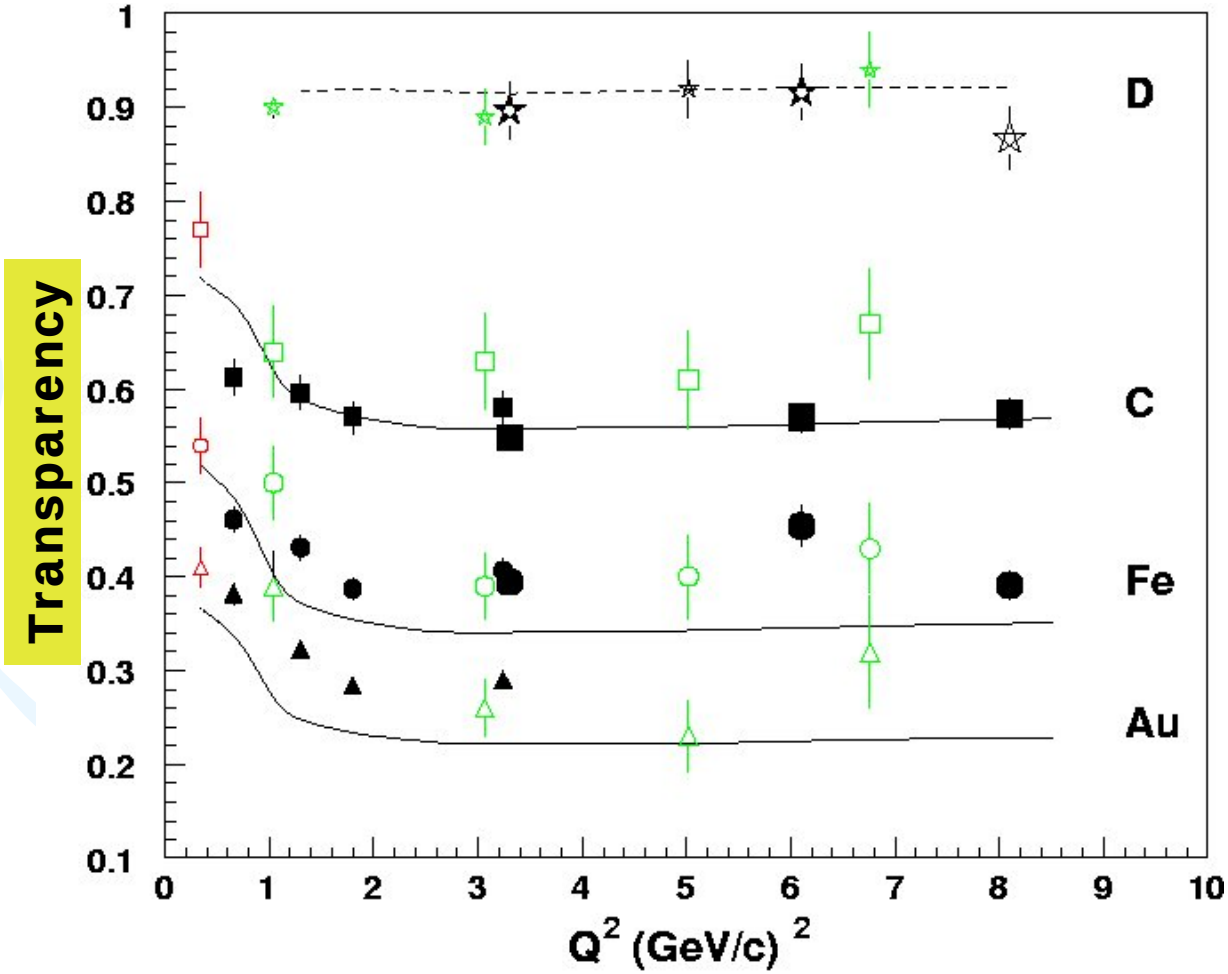
CT can be observed experimentally by :

- Measuring a reduced attenuation of particles as they exit the nucleus

AND/OR

- Measuring a decrease in production of particles produced via two-step rescattering mechanisms (few-body nuclei)

Quasi-free A(e,e'p) : No evidence of effects associated with CT

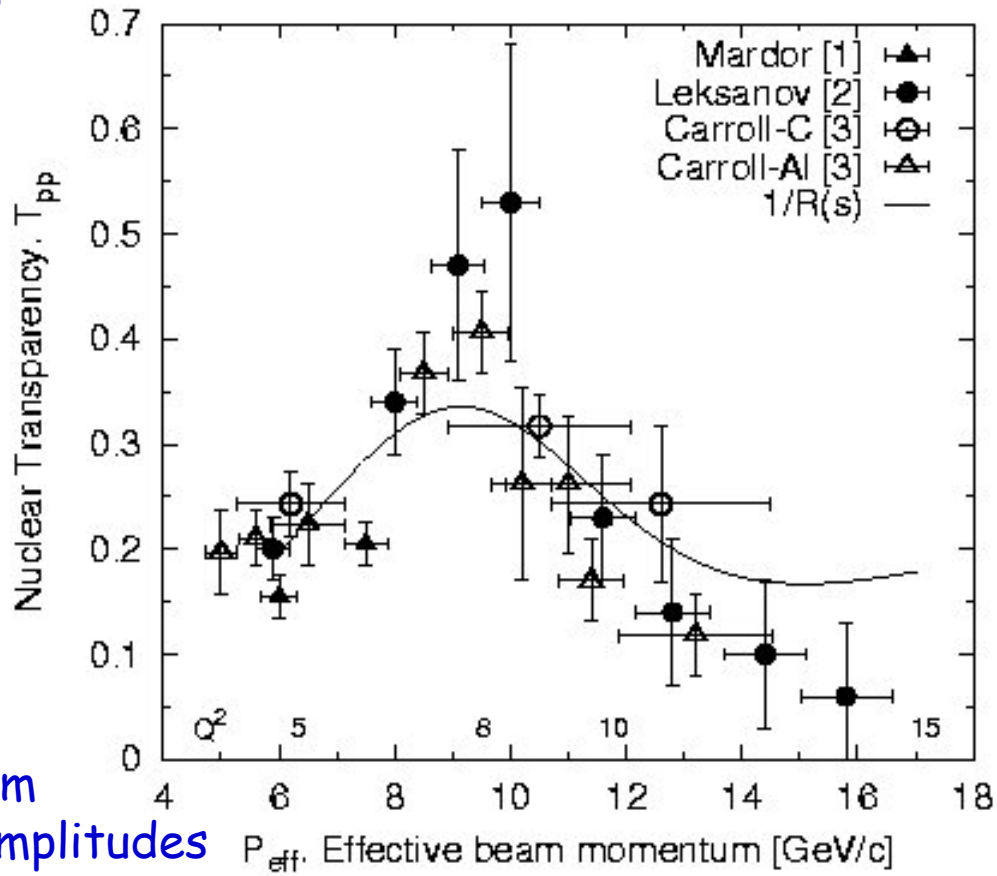


JLab data SLAC data Bates data

Quasi-elastic A(p,2p) : E834 and E850

Peak in nuclear transparency at about 9.5 GeV/c incident momentum

Neither the Glauber model nor the naïve prediction of CT model can explain the data

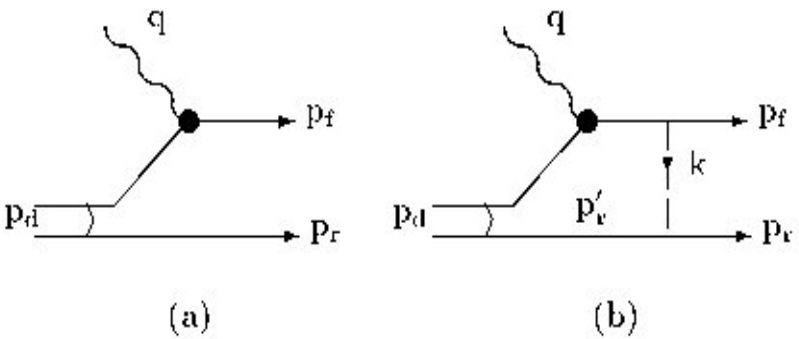


Two explanations of the surprising decrease were given :

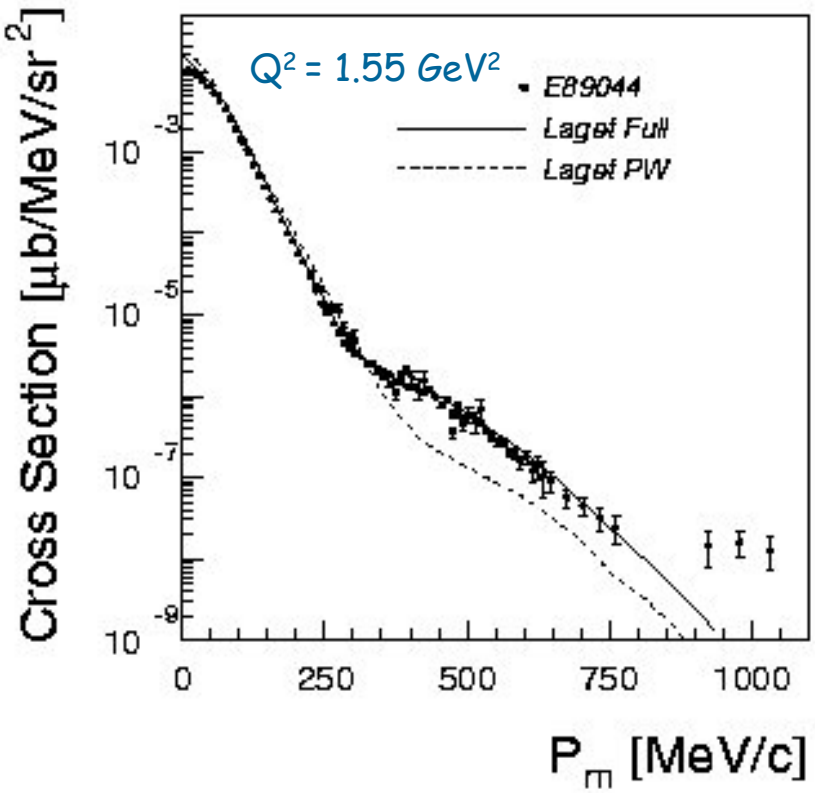
Ralston and Pire :
Interference between short and long distance amplitude in the free p-p cross-section where the nuclear medium acts as a filter for the long distance amplitudes

Brodsky and De Teramond : Unexpected decrease could be related to the crossing of the open-charm threshold

CT in few-body system : Rescattering



Hall A : ^{3}He(e,e'p)d experiment



- E94-019 CLAS experiment : (e,e'N) and (e,e'NN) on ^{2}H, ^{3}He and ^{4}He
- Probability for the projectile to re-interact will be achieved by selecting double scattering kinematics.
- The measured ratios are : $T=\sigma(e,e'p)^{exp}/\sigma(e,e'p)^{PWIA}$

$T^{double}=\sigma(e,e'NN)^{exp}/\sigma(e,e'NN)^{PWIA}$

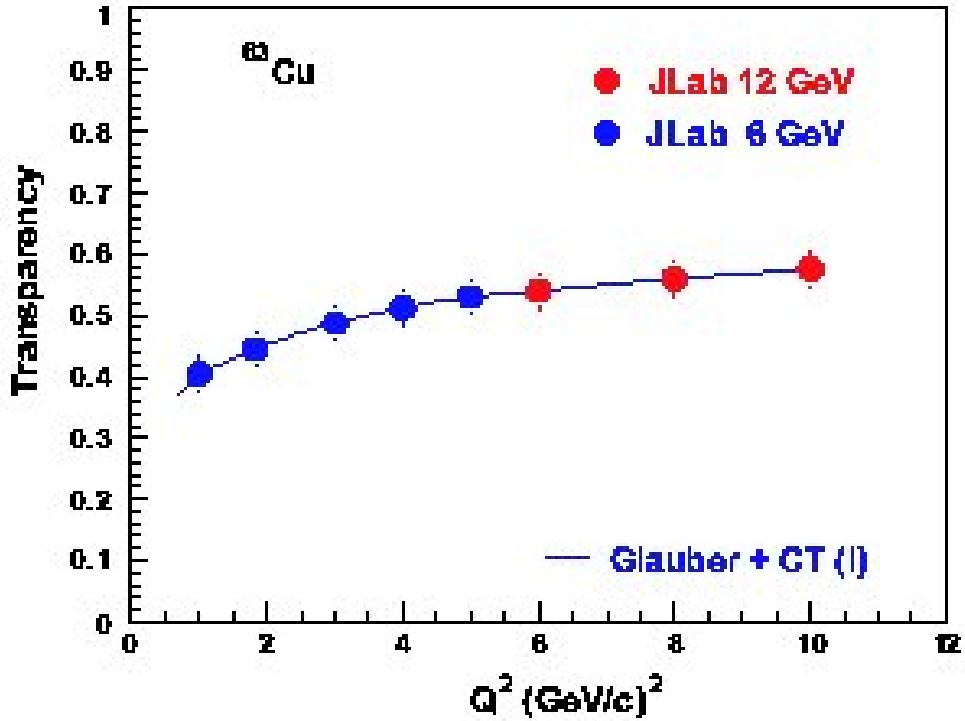
$R=\sigma^{double}/\sigma^{single}$

Pion electroproduction at HallC

Intuitively, one expects an earlier onset of CT for meson production

Hall C : data has been taken last couple of months for pion electroproduction with 5.75 GeV electron beam

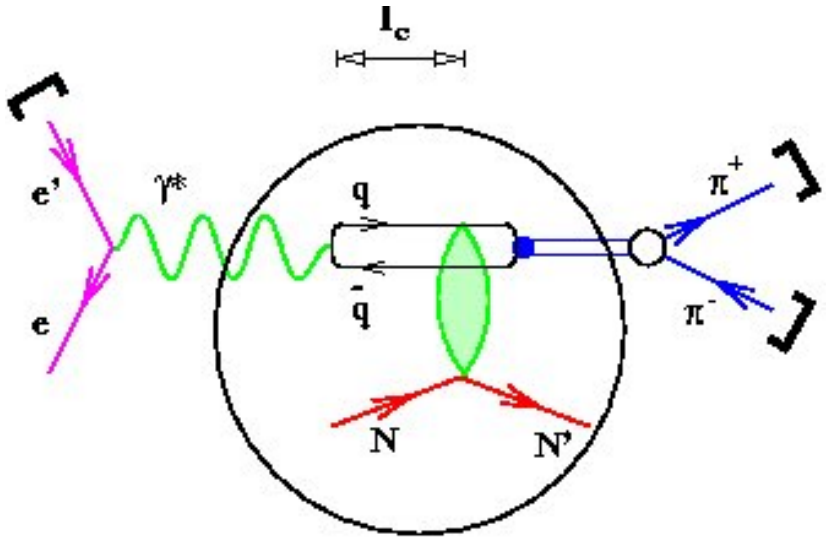
E02-010 experiment in hall A is planning to measure $\gamma n \rightarrow \pi^- p$ and $\gamma p \rightarrow \pi^+ n$ from D and ^{12}C

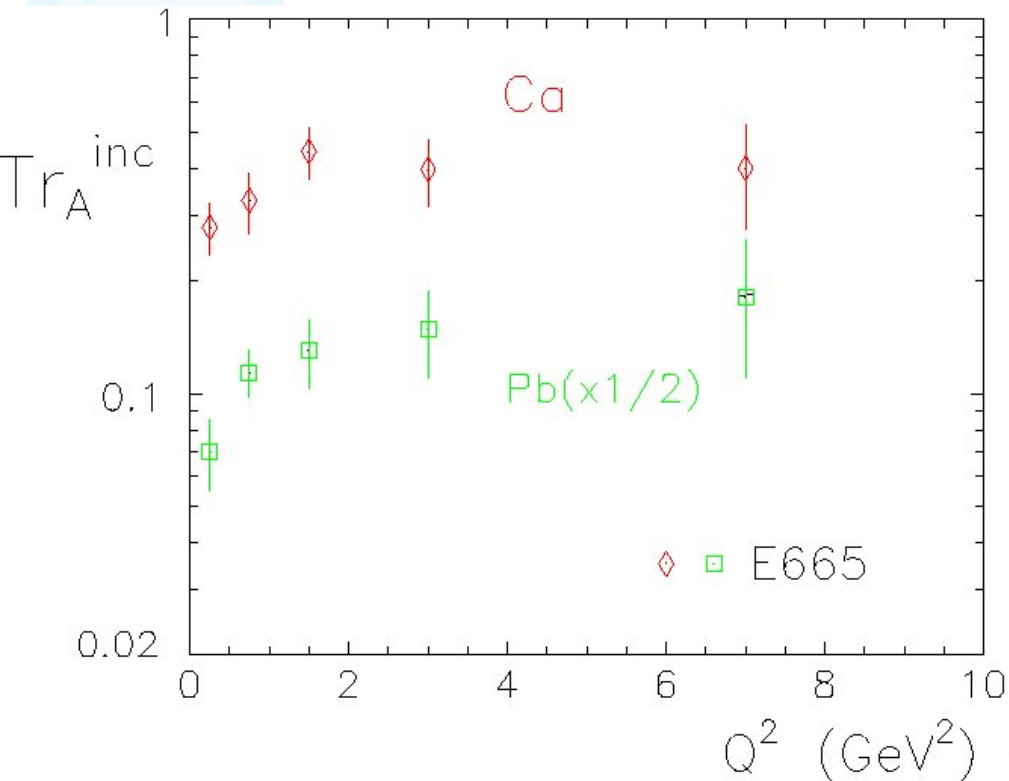


ρ^0 electroproduction (I)

Incoherent ρ^0 electroproduction on nuclei

Detected particles are :
Scattered electron and the π^+ and π^- from ρ^0 decay





Finite propagation distance (lifetime)
l_c for the qqbar virtual state

$l_c = 2\nu/(2M^2 + Q^2)$

M is the mass of qqbar
For experimentalist M is the mass of the vector meson produced

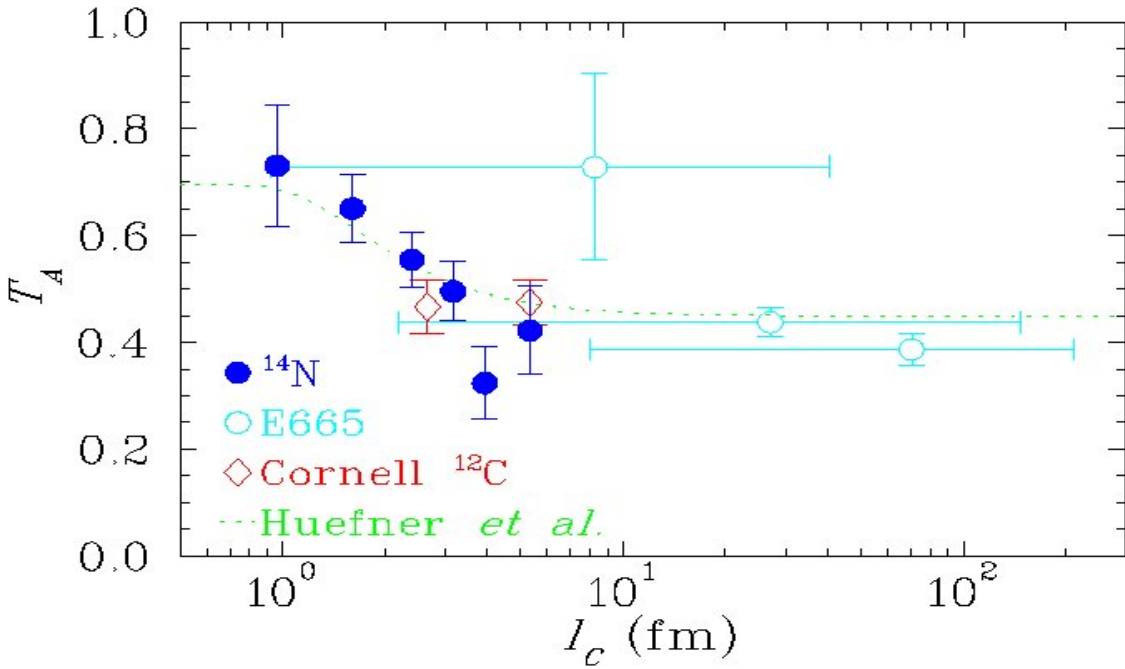
ρ^0 electroproduction (II)

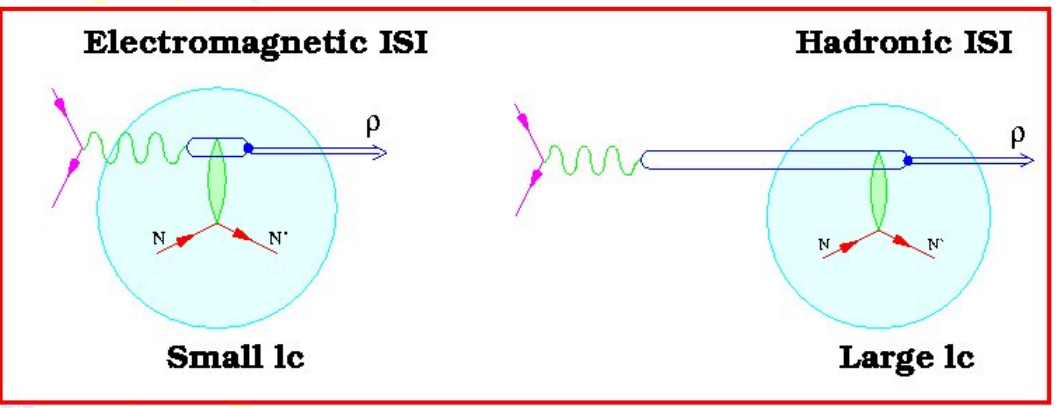
$l_c = 2\nu/(2M^2 + Q2)$

The nuclear transparency depends strongly on the coherence length for l_c below 10 fm

$\Rightarrow$ Coherence length effect (CL)

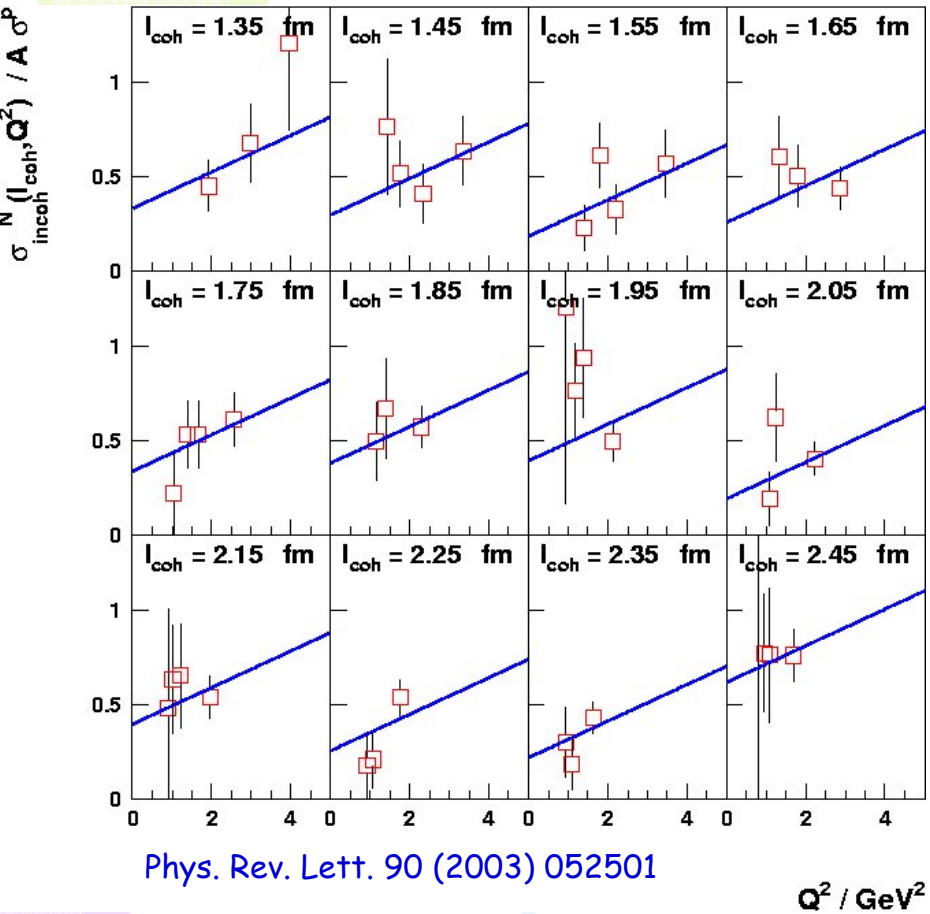
Q^2 increases $\Rightarrow$ T_A increases





- Coherence Length effect can mimic CT signal
- To be safe, one should keep l_c fixed and measures the Q^2 dependence of T_A

ρ^0 electroproduction (III)



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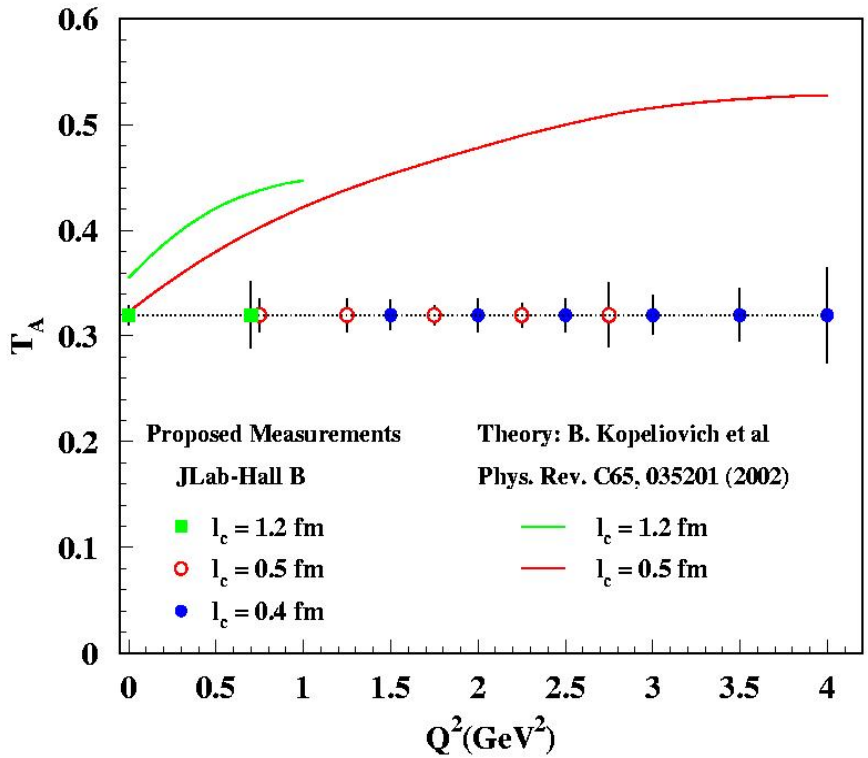
CLAS E02-110 projected uncertainites

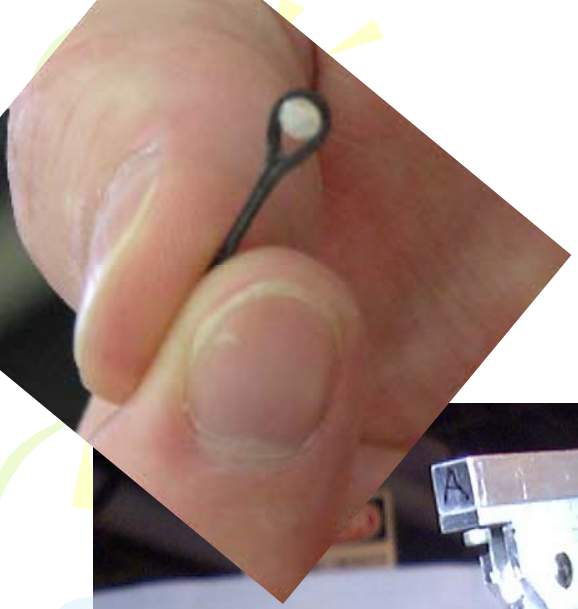


HERMES Nitrogen data : $T_A = P_0 + P_2 Q^2$

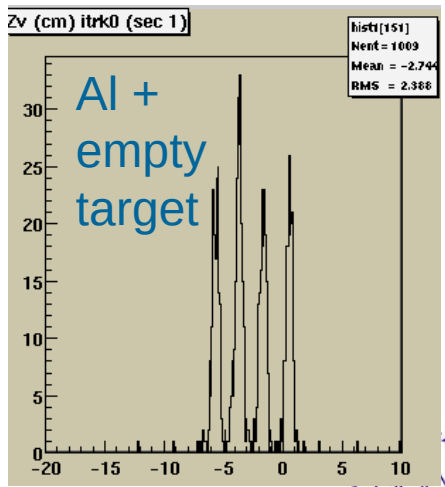
$P2 = (0.097 \pm 0.048_{stat} \pm 0.008_{syst})\ GeV^{-2}$

Data was taken this year
Analysis is in progress

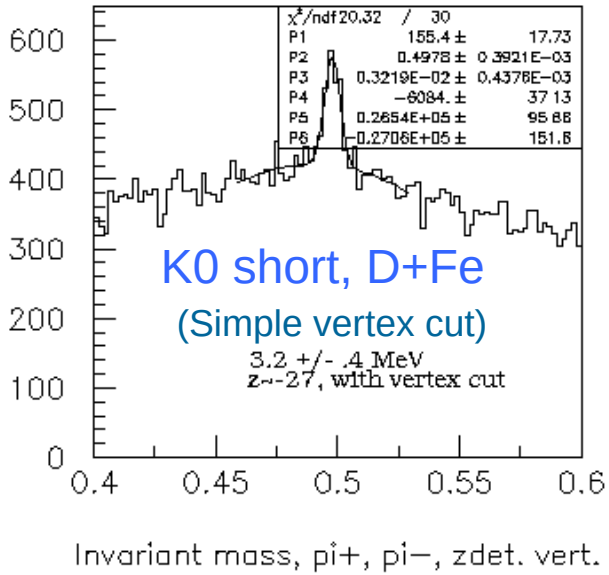
CLAS EG2 Targets

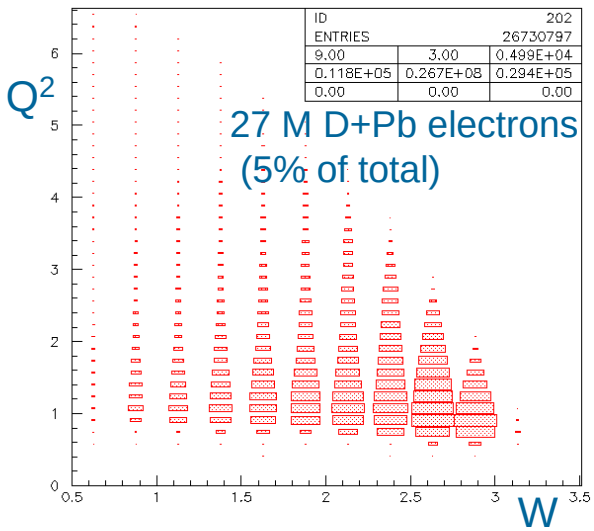


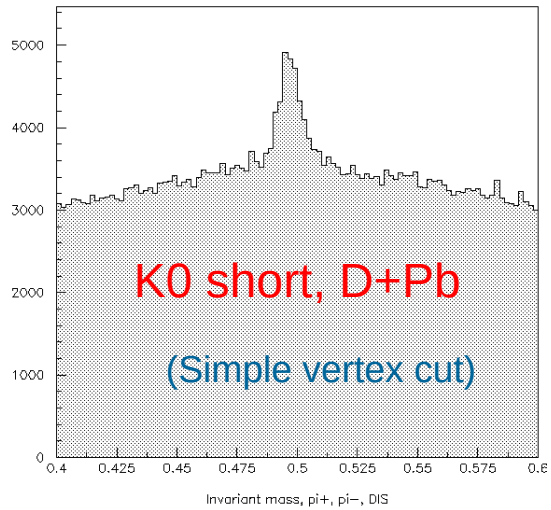
- Two targets in the beam simultaneously
- 2 cm LD2, upstream
- Solid target downstream
- Six solid targets:
  - -Carbon
  - -Aluminum (2 thicknesses)
  - -Iron
  - -Tin
  - -Lead

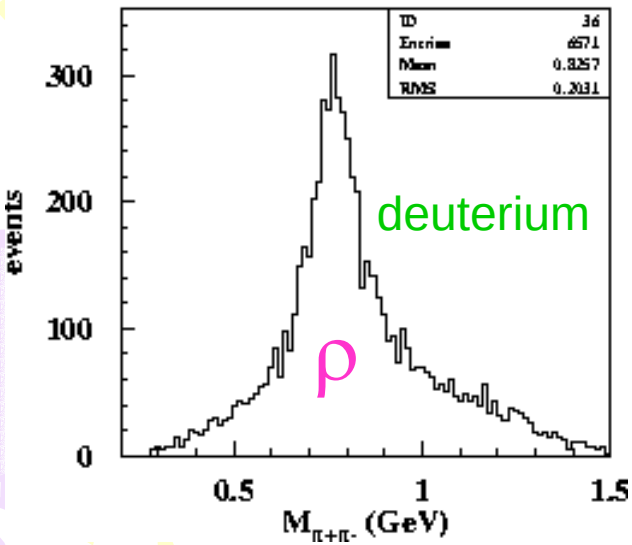


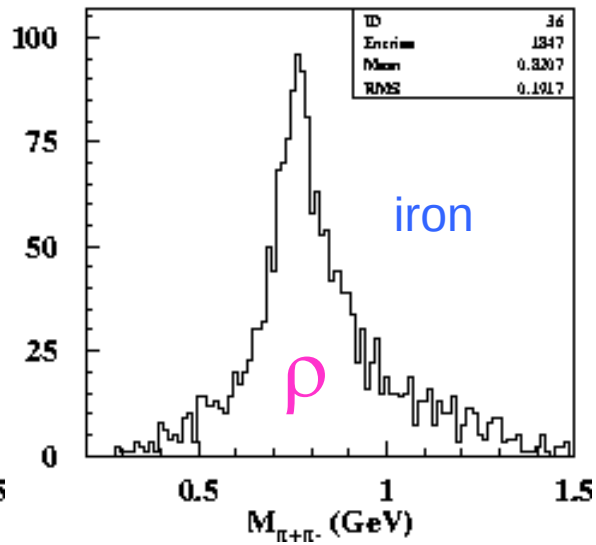
CLAS EG2
Online Physics Results

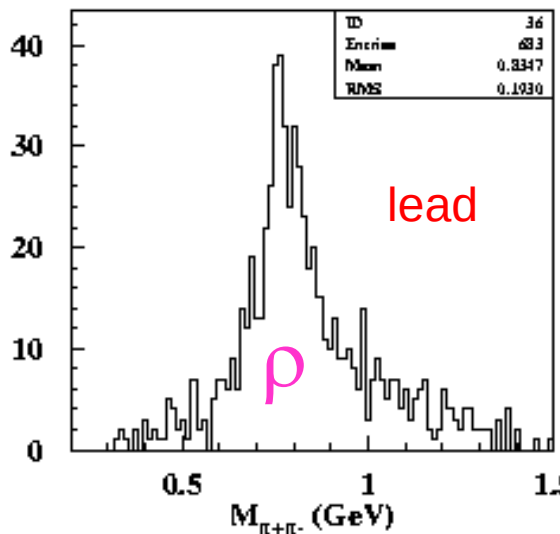




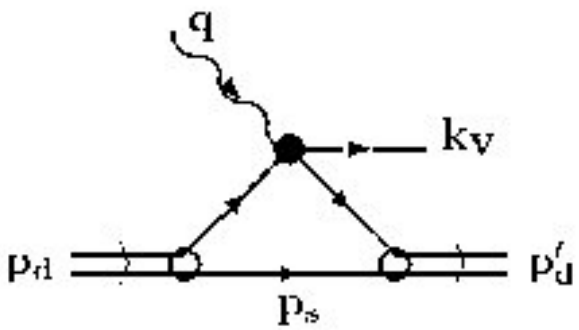




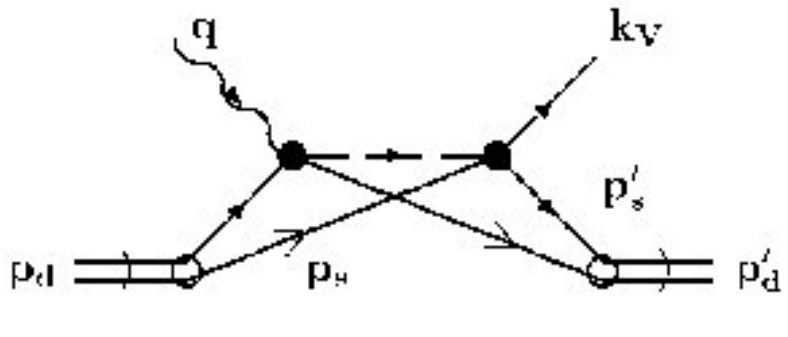




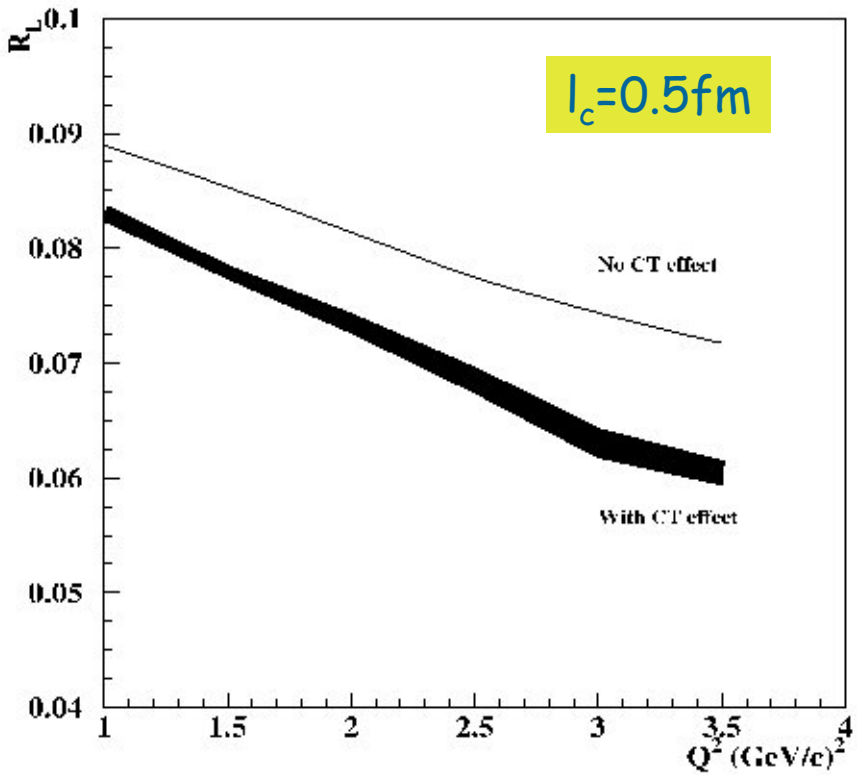
Coherent vector meson electroproduction on deuterium at CLAS



(a)



(b)



E02-012 CLAS experiment is planning to measure coherent ρ, ω and ϕ electroproduction on deuterium

$R_L=(d\sigma_L(Q^2,l_c,t_1)/dt)/(d\sigma_L(Q^2,l_c,t_2)/dt)$

$-t_1=0.4(GeV/c)^2$ Double scattering

$-t_2=0.8(GeV/c)^2$ Single scattering

High energy measurements at Fermilab : E791

Di-jets diffractive dissociation : Aitala et al. PRL86 (2001) 4473

π + (C,Pt) $\Rightarrow$ Diffractive dissociation into di-jets

$$\psi_\pi = \lambda|qq\rangle + \beta|qqg\rangle + \gamma|qqgg\rangle + \ldots$$

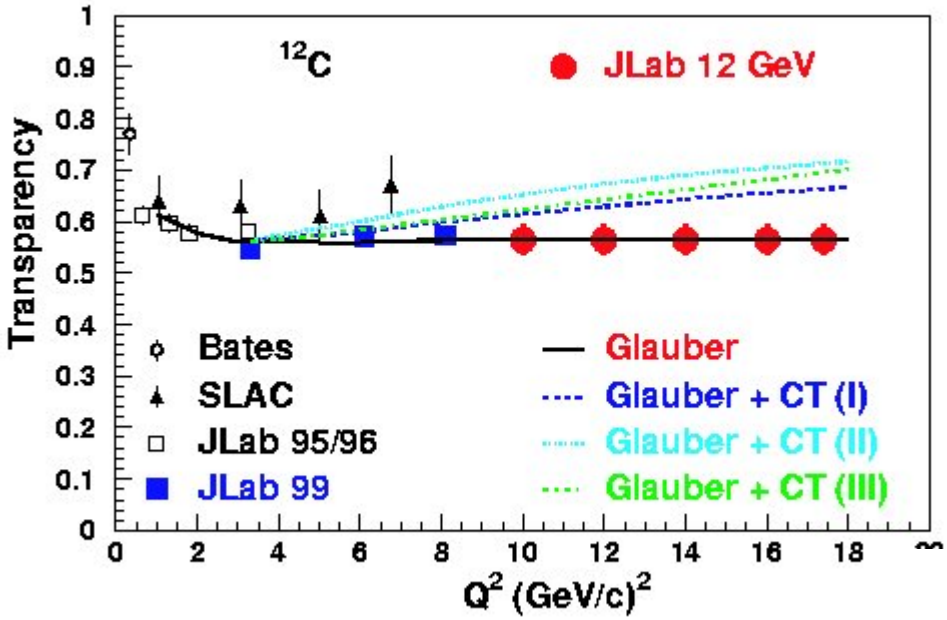
qq materialize into di-jets

$\sigma = \sigma_0 A^\alpha \qquad \alpha = 1.6 \pm 0.1$

in agreement with CT prediction
Frankfurt, Miller and Strikman PLB301(1993)

NB : Typical π-nucleus interaction is ~ $A^{2/3}$

What could be done at 12 GeV ?



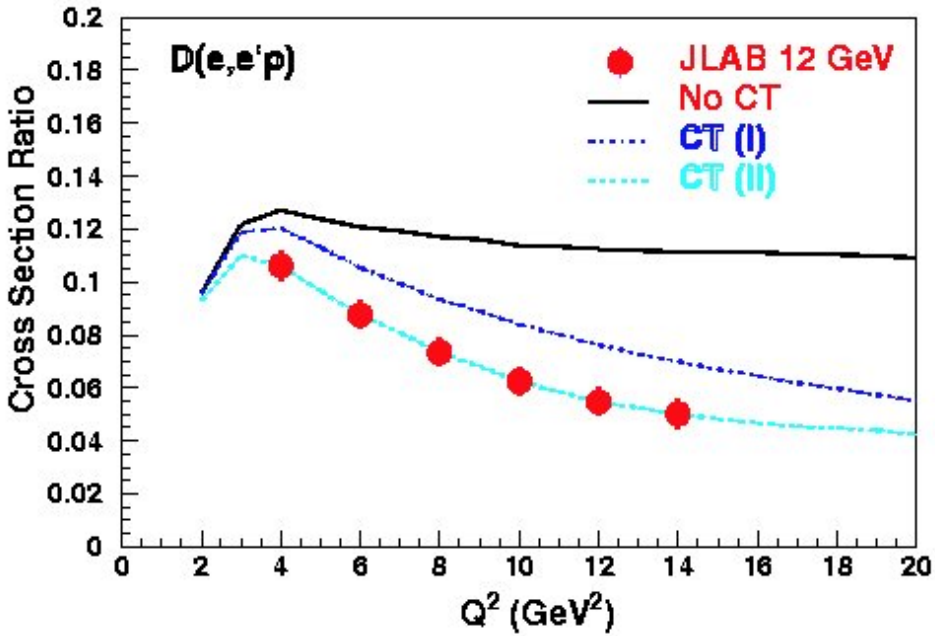
Quasi-free A(e,e'p):
Extend the Q^2 range up to 18 GeV^2

Is any increase of T_A considered as a non-ambiguous signal of CT ??

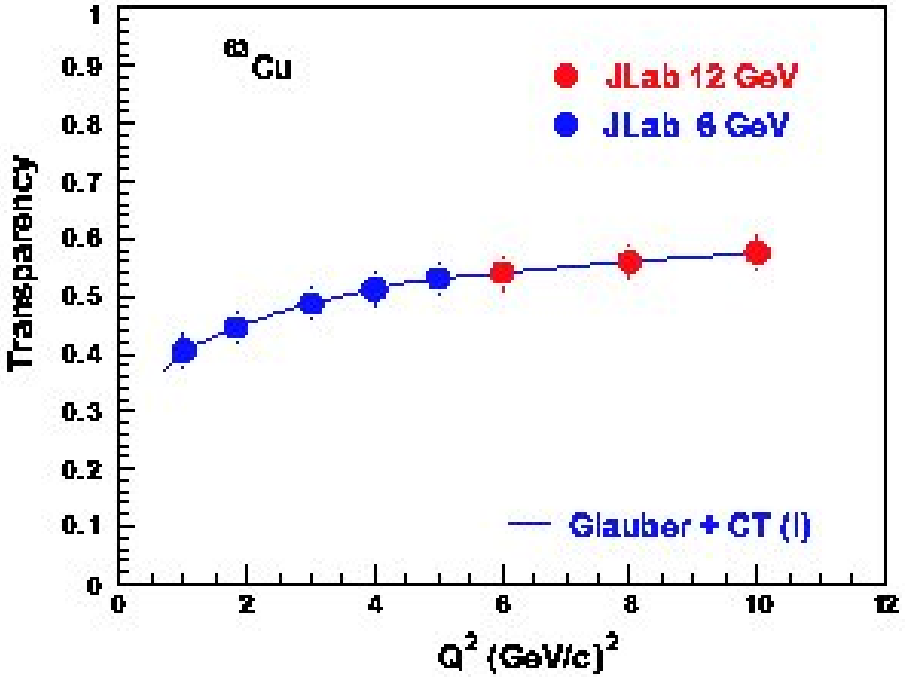
$R=\sigma(p_m=400MeV/c)/\sigma(p_m=200MeV/c)$

CT(I) : Calculation with ΔM^2 = 0.7 GeV^2
Farrar, Liu, Frankfurt and Strikman (1988)

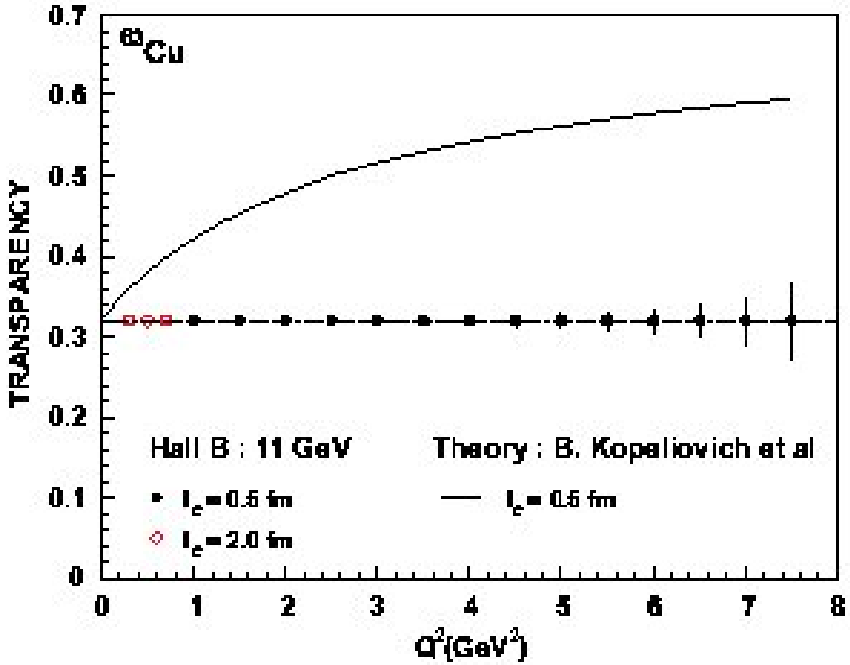
CT(II) : Calculation with ΔM^2 = 1.1GeV^2
Sargsian, Private communication



What could be done at 12 GeV ? (cont.)



Pion electroproduction in hall C



Incoherent ρ^0 electroproduction at CLAS

J/ψ production near threshold

Projected uncertainties on the ratio
Of cross-sections for 2000 hours at
CLAS with 11 GeV beam

$l_f \sim 2/(m_{\psi'} - m_{J/\psi})[E_{J/\psi}/2m_c] \sim 0.22E_\gamma$

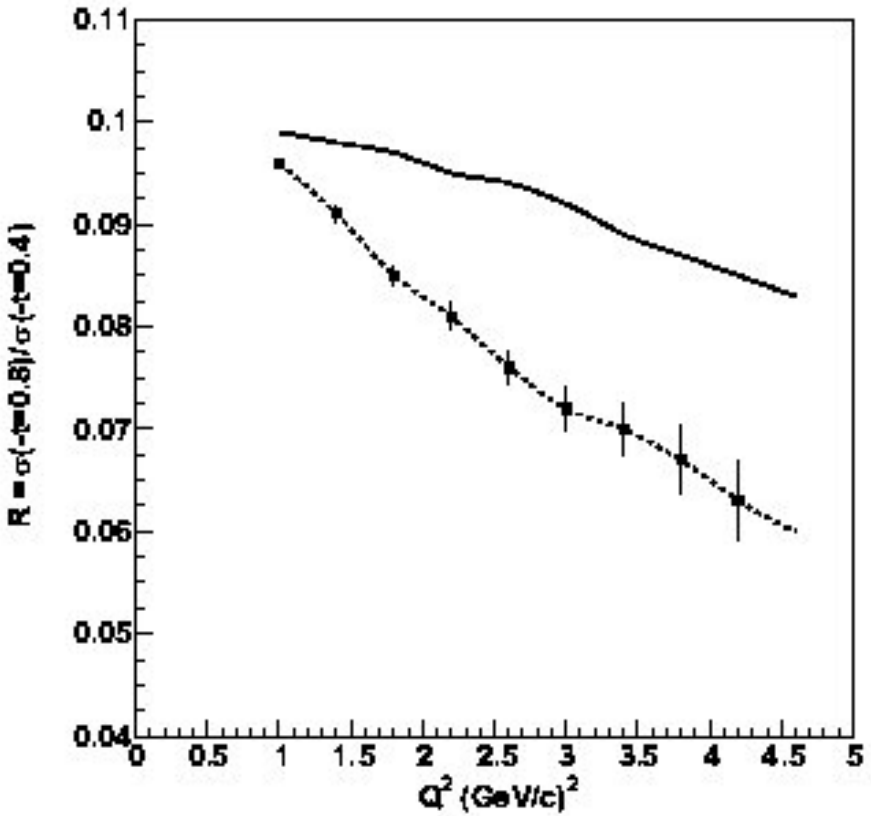
The study of the A dependence of the
J/ψ photoproduction(SLAC) at 20 GeV

$\Rightarrow \sigma_{\psi N} = 3.5 \pm 0.8 \pm 0.5$ mb

In contrast, a calculation by Brodsky
Based on Van der Waals potentiel

$\Rightarrow \sigma_{\psi N} = 7$ mb

$\sigma_{\psi N}$ is an important input to quark-gluon
Plasma physics



Near threshold measurements are required to clarify the situation

Summary and outlook

- Vigorous program to look for the onset of CT
- Chances are high to see the manifestation of CT at 6GeV
- Straightforward extension to 12 GeV program
- New windows open for Charm studies
- New ideas ??