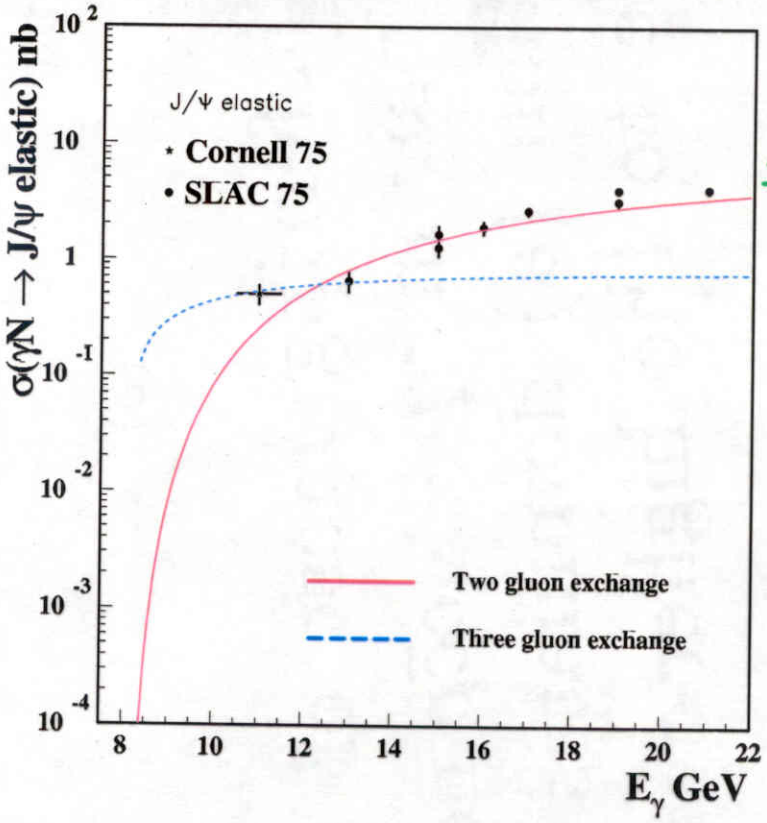
J/ψ PHOTOPRODUCTION AT JLAB

- What is a J/ψ
- Proton Cross Section
- A-dependence to obtain $\sigma_{\psi N}$
- Connections to other physics
- Sub-threshold production on nuclei (E03-008)
- Other possibilities

WHAT IS A J/ψ

- Vector meson ($J^{PC} = 1^{--}$)
- $c\bar{c}$ bound in $1S$ state
- Same quantum numbers as photon: "easy" for photon to fluctuate into.
- Mass 3.097 GeV, width 0.087 MeV
- heavy c quark mass (1.3 to 1.7 GeV) makes QCD calculations easier than for light quarks.

PROTON CROSS SECTION



⇒ LOTS MORE DATA AT HERA TO 20000 GeV: AGREE WITH QCD CALC'S WITHIN SYST. OF CALCS (μ, etc.)

- Total cross section small (nb range)
- Overall shape dominated by increase of $-t_{min}$ at threshold.
- Cross section flattens out near threshold, if Cornell point is right.
- Possible explanations are 3-gluon model of Laget et al., or dipole-like form factor of Strikman et al.
- More data needed: with 12 GeV "for free" from Hall D, dedicated runs Hall C/A.

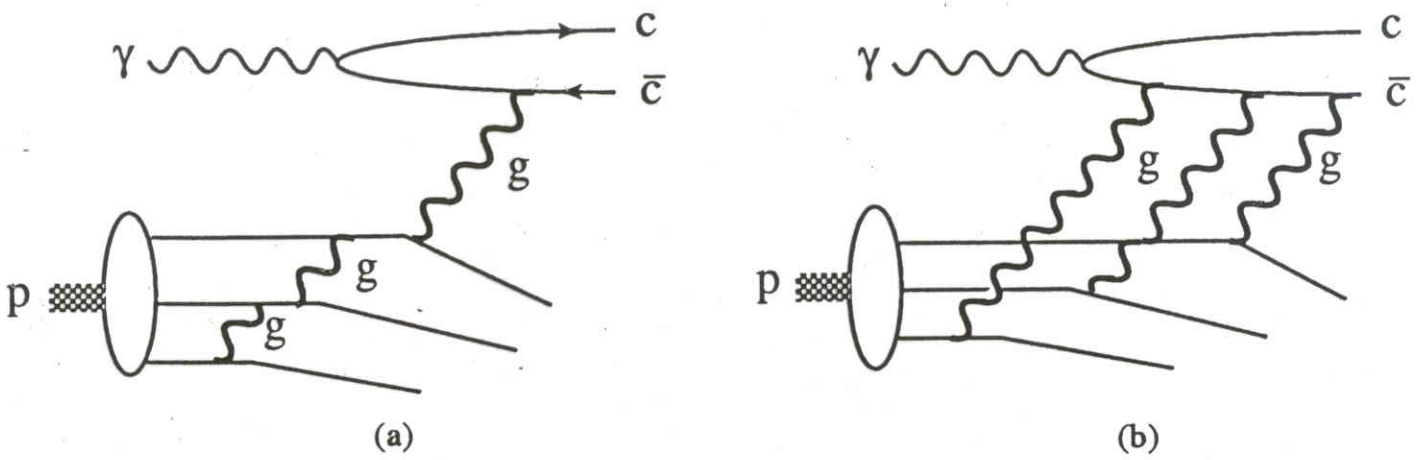
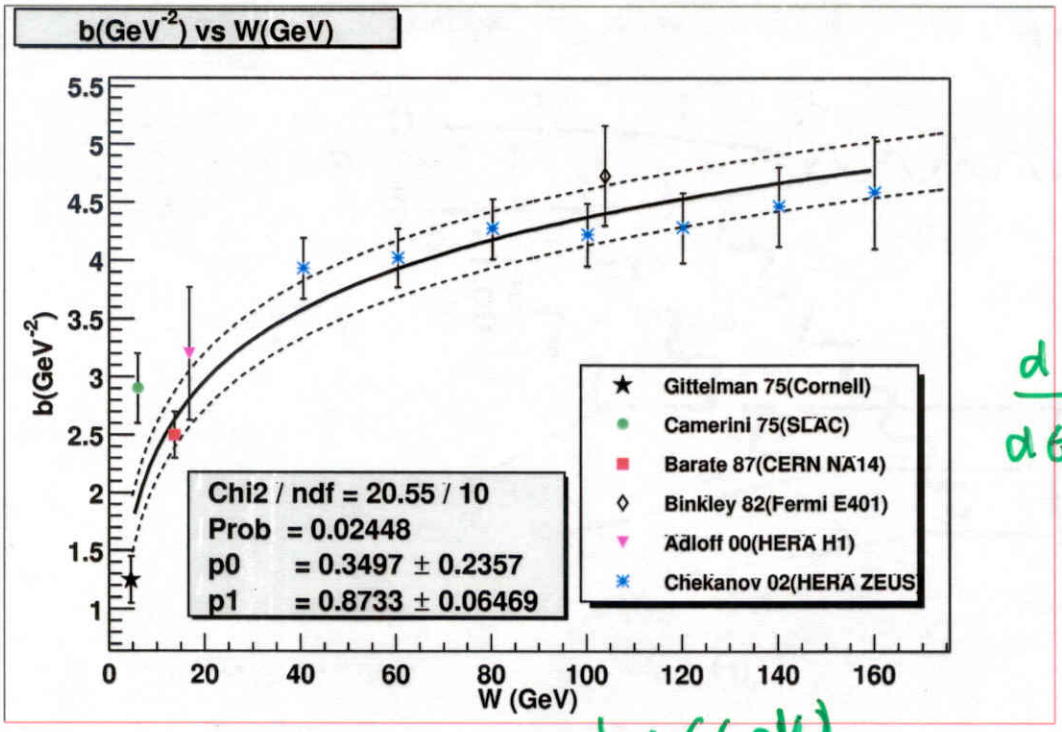


FIG. 2. Two mechanisms for transferring most of the proton momentum to the charm quark pair in $\gamma p \to c\bar{c}p$ near threshold. The leading twist contribution (a) dominates at high energies, but becomes comparable to the higher-twist contribution (b) close to threshold.

FROM BRODSKY, CHUDAKOV, HOYER, AND LAGET

PROTON CROSS SECTION SLOPE



b

$\frac{d\sigma}{dt} = \sigma_0 e^{+bt}$

W (GeV)

- At high energy, b has typical diffractive value ($6\ \mathrm{GeV}^{-2}$), consistent with long-distances interaction.
- b decreases rapidly near threshold, as has been seen in other exclusive reactions.
- Small values of b are consistent with increased transverse localization of process near threshold.
- Experiments near threshold inconsistent: need much better data (including isolation of exclusive process from inelastic production).

SLAC E160

A–Dependence of J/ψ and ψ' Photoproduction

Goals

- **Understand cause of J/ψ suppression in heavy–ion collisions**
- Explore creation and interaction of ψ and ψ' in nuclei
- Understand why VMD and geometrical cross sections differ

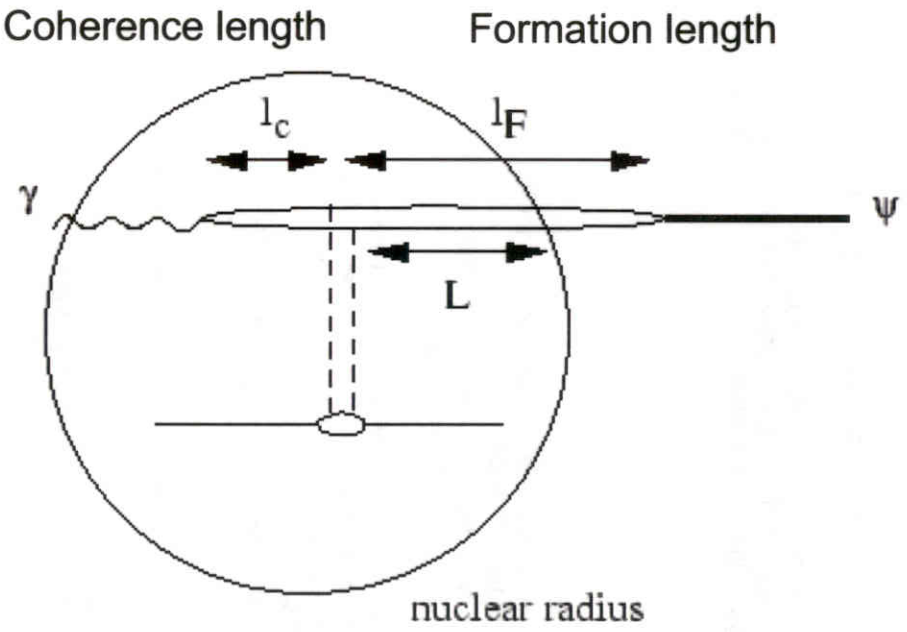
Measurement

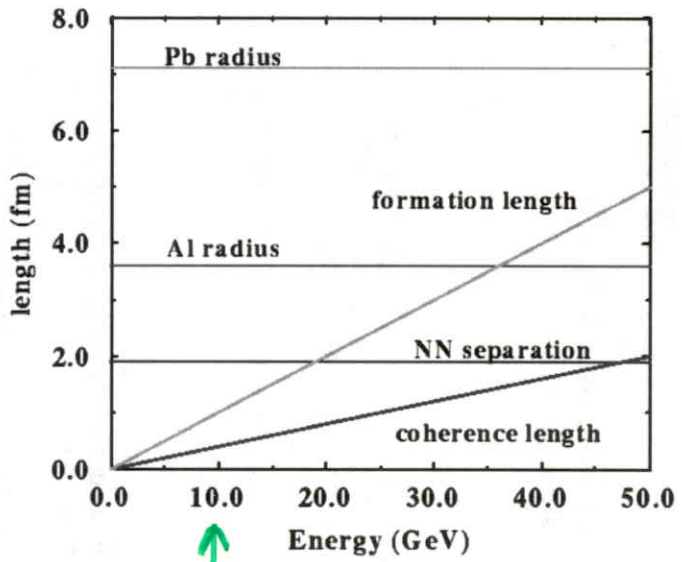
- Reconstruct J/ψ and ψ' from $\mu^+ \mu^-$ pairs
- Be, Al, Cu, Pb targets
- Photon energy 15, 25, 35 GeV

Results

- Nuclear A–dependence
- ψ –nucleon cross section
- Ψ'–nucleon cross section

Length Scales for J/ψ Propagation in Nuclei





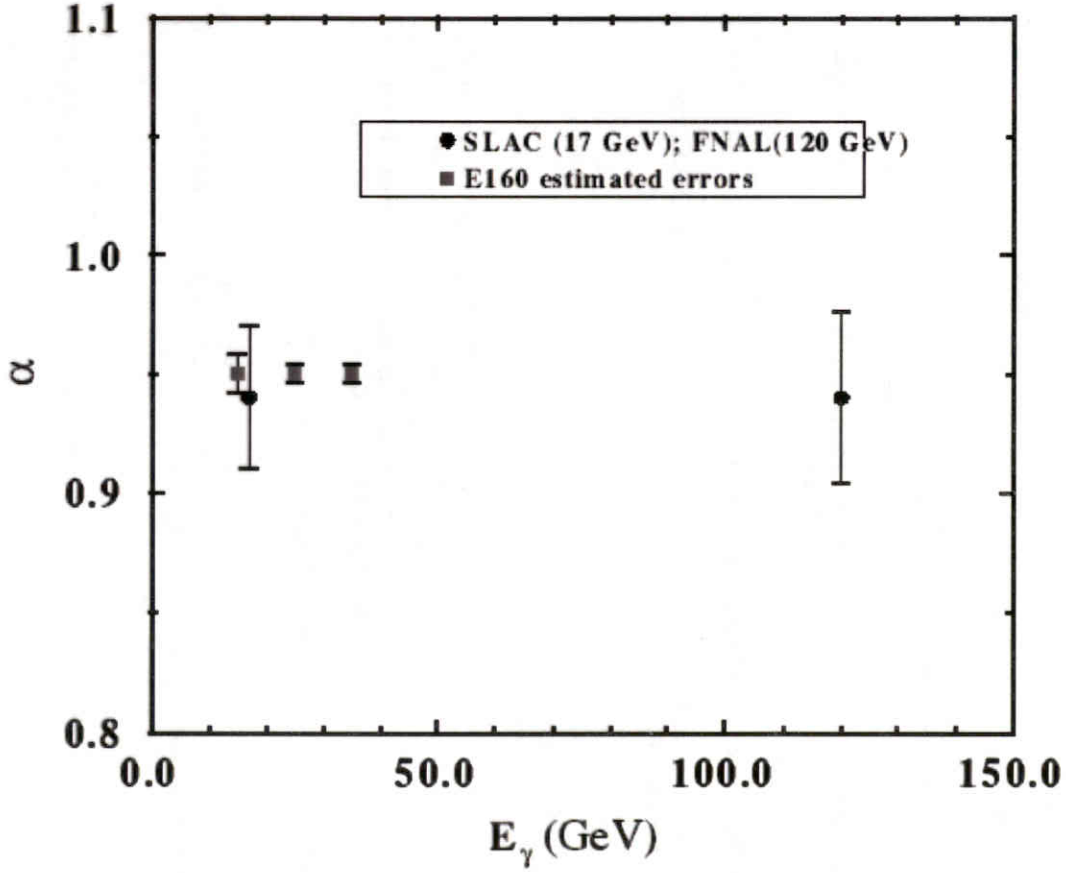
JLAB

E160 range

E160 Projected Results for A-Dependence

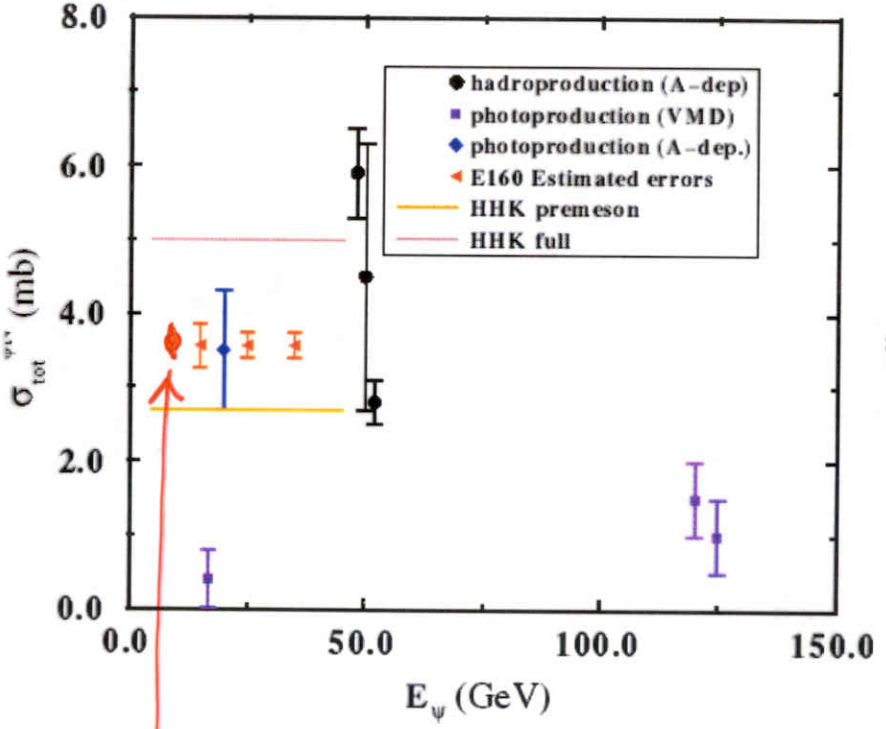
$\sigma(\psi,N) = A^{\alpha}$ - DO DATA FOLLOW THIS FORM IS FIRST QUESTION!

Results to constrain ψ formation and coherence lengths

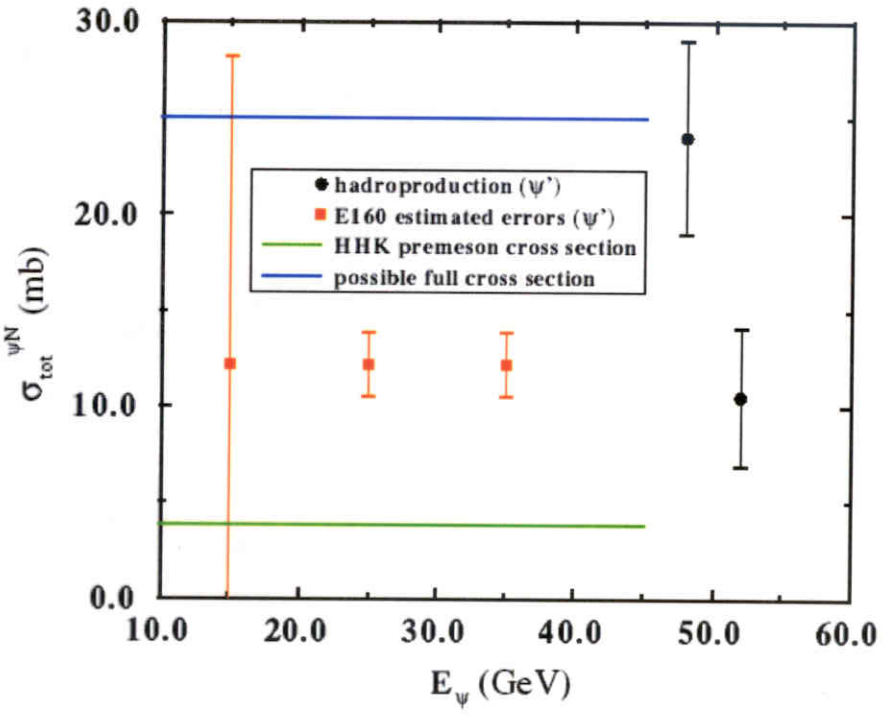


E160 Possible Results for Total ψ–N Cross–Sections Compared to Theory and Previous Data

ψ–Nucleon



Ψ'–Nucleon



POSSIBLE JLAB EXP.

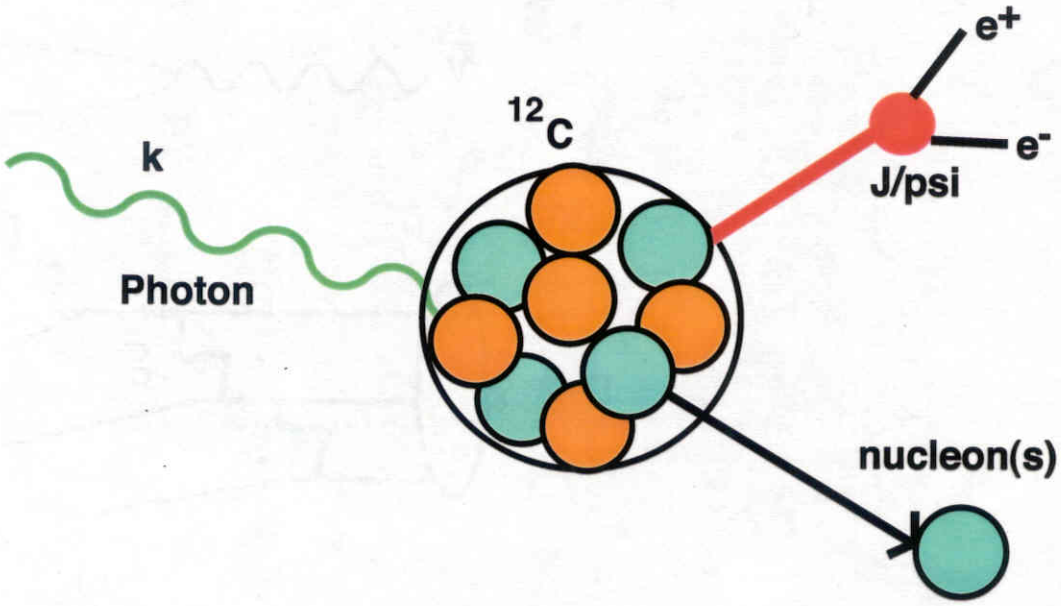
Horizontal bars represent range of theoretical estimates

Ψ'→ Ψ Important: Need to Measure Both

CONNECTION TO QGP

- In quark-gluon plasma search at RHIC J/ψ suppression is one of gold-plated signatures
- Need better understanding of how J/ψ produced and propagate.
- Data with simple photon probe provides test of theories
- Can distinguish between theories in which J/ψ suppression is caused by QGP or by "ordinary" nuclear physics.
- Sub-threshold kinematics ensures high local density, similar to heavy ion collisions.
- In future, use of heavier nuclei can help pin down J/ψ -nucleon cross section.

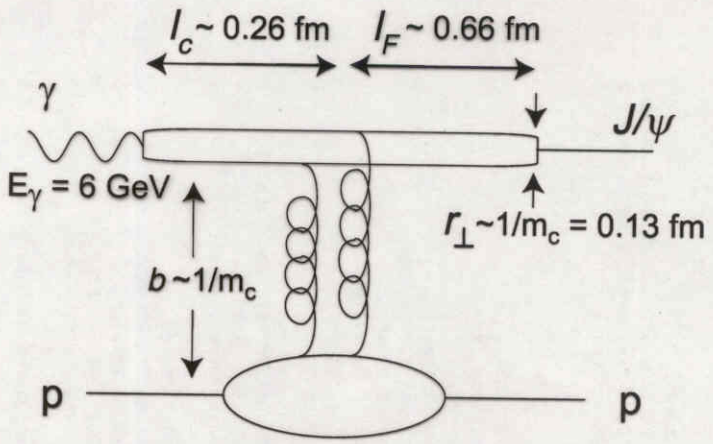
SUB-THRESHOLD PHOTOPRODUCTION ON NUCLEI (E03-008)



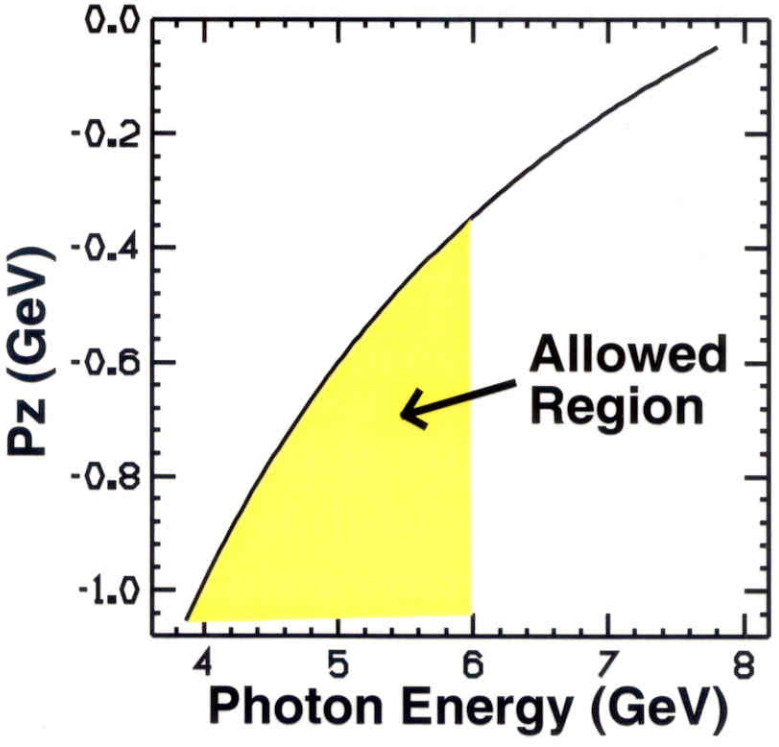
- Threshold for free nucleon is $k = 8.2$ GeV
- Threshold for ^{12}C is 3.7 GeV
- Thus 6 GeV at JLab is sub-threshold to free nucleon
- Dominated by ^{12}C breakup to nucleon clusters (requires > 350 MeV/c momentum for bound nucleon)
- Coherent (^{12}C remains intact) is strongly suppressed by form factor
- Inelastic (additional mesons) is suppressed by phase space

MOTIVATION

- Study how nucleus differs from a loosely bound system of quasi-independent nucleons
- Study short range effects, including hidden color configurations, multi-nucleon correlations.
- Use heavy quarkonium
  - to ensure a hard scale ($m_c^2 > \Lambda_{QCD}^2$)
  - corresponds to small longitudinal coherence length $2k/4m_c^2 \approx 0.3$ fm and small transverse size $1/m_c = 0.13$ fm: picks out small distance scale Fock states.
  - because charm quarks are rare in nucleus so quark exchange mechanism suppressed.



WHY IS 6 GEV OPTIMAL?



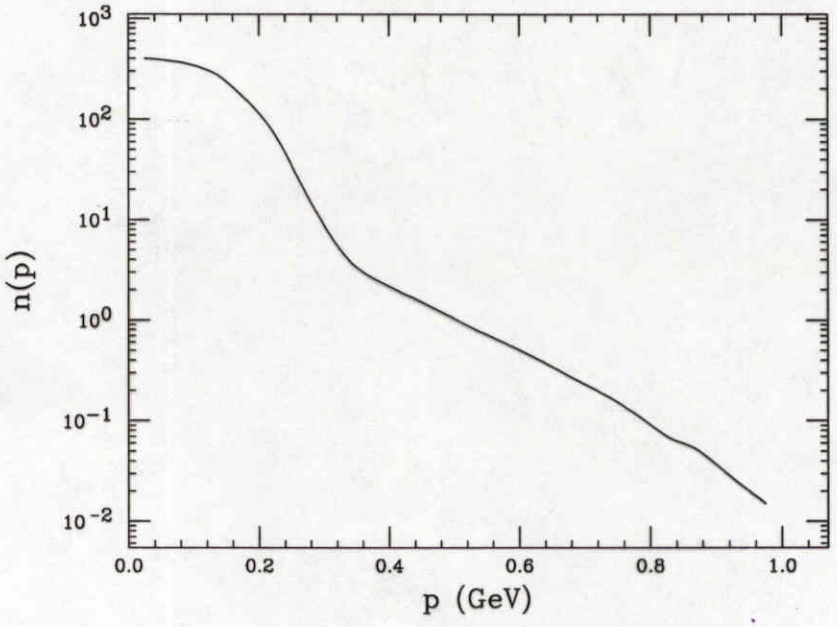
- Minimum nucleon momentum required for quasi-free production decreases with increasing photon energy.
- To emphasize region where short-range effects important, we want $-P_Z > 0.35$ GeV, or $k < 6$ GeV.
- Rates drop very rapidly to zero at threshold of 3.7 GeV, because minimum $-t_{min} \rightarrow 1.7$ GeV^2, and form factor (e^{bt}) suppresses cross section.
- Conclude that bremsstrahlung spectrum with endpoint 6 GeV is optimum for this experiment.

SUB-THRESHOLD CROSS SECTION ESTIMATES

- For rough estimates, we used simple Fermi-smearing model

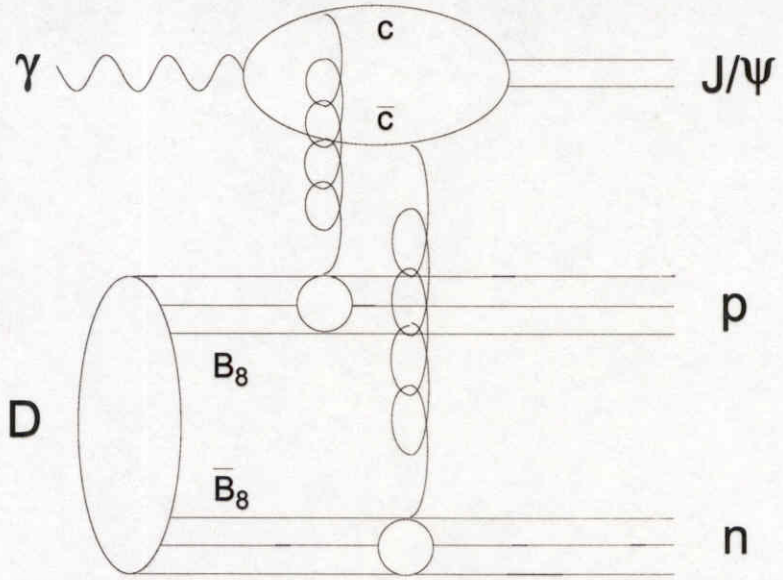
$$d\sigma = \int d\sigma_0/dt(s,t) n(p) d^3p dt \quad (1)$$

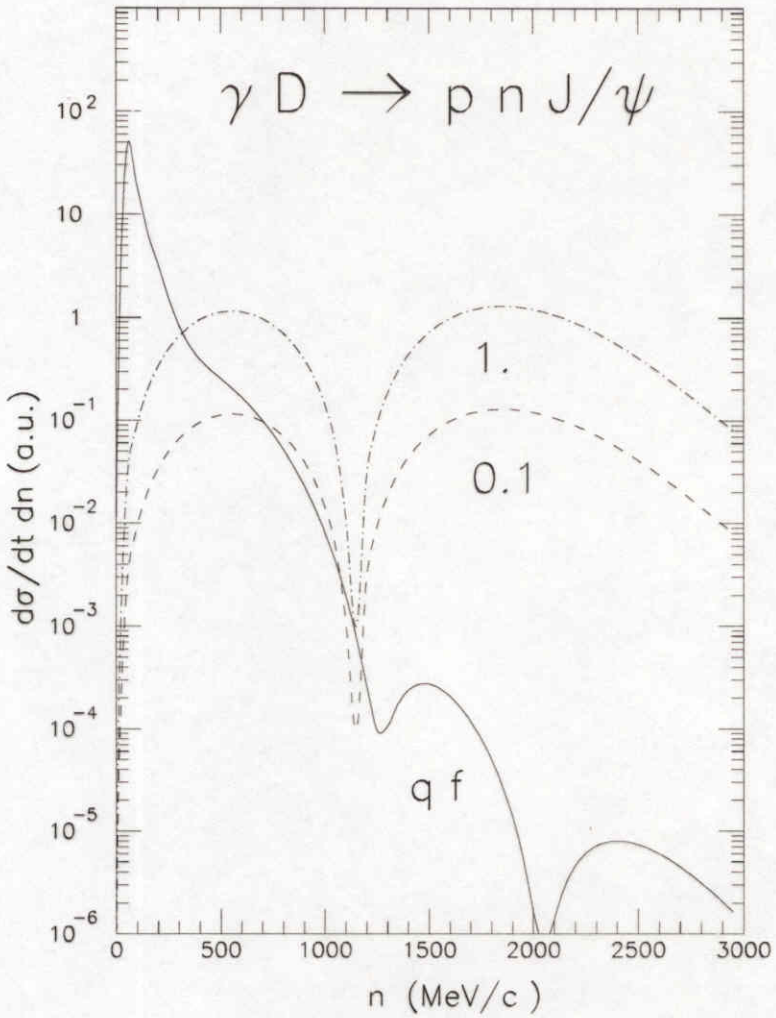
where integral limited to kinematically allowed region, $n(p)$ from $(e, e'p)$ data X. Ji and J. Engel, Phys. Rev. C40, R497 (1989)



- Integrated over photon energy k using $1/k$ distribution
- Using Cornell fit $d\sigma_0/dt = 1.01e^{1.25t}$ nb/GeV^2, find about 2 pb/nucleon.
- could be enchanged by hidden color configurations.

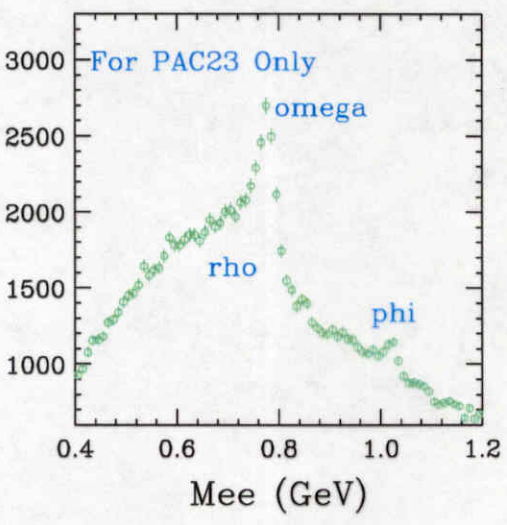
HIDDEN COLOR CONFIGURATION

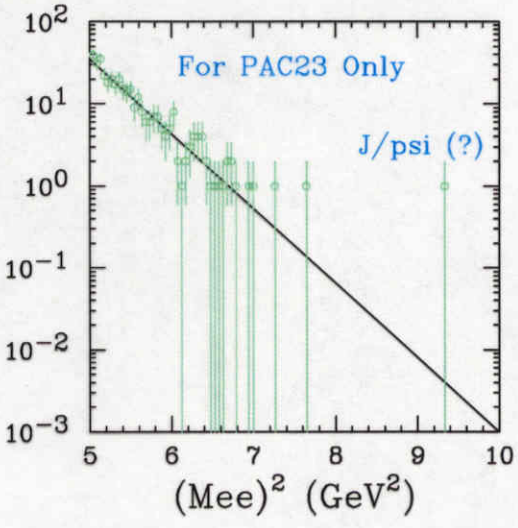




EXPERIMENTAL PLAN

- Electron beam goes through thick (8% r.l.) target: makes photon beam, plus equivalent 3% quasi-real electroproduction
- Identify J/ψ from 6% B.R. to each of e^+e^- and $\mu^+\mu^-$
- Measure leptons with good resolution in spectrometers.
- Preliminary Hall B data at 5.7 GeV shows technique should work.





OTHER POSSIBILITIES

- Single-spin asymmetry using linearly polarized photons (Hall D).
- Electroproduction of J/ψ
- Photoproduction of η_C, D^0, Λ_c

SUMMARY

Charm is coming to JLab (maybe sooner than you thought!).