Charm at threshold and ψ-N cross-section

Presented by E.Chudakov, JLAB

Main goals:

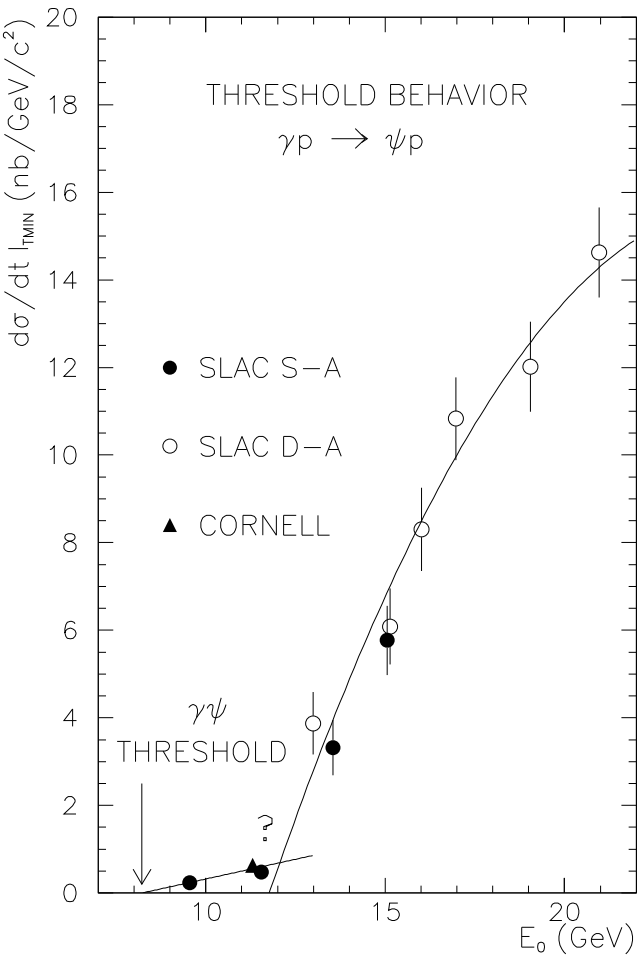
- Measure $\frac{d\sigma}{dt}$ for γN $\rightarrow$ J/ψ(1S)N in a range 8.7-11 GeV
- Measure $\sigma_{\psi N}$ by measuring $\frac{d\sigma}{dt}(A)$ for γA $\rightarrow$ J/ψ(1S)X. Since Fermi motion matters, this measurement should be based on the first (cross section measurement)
- Further studies: "hidden color", bound states

In this talk:

- Charm photoproduction cross section
- $\sigma_{\psi N}$ - theoretical and practical interest
- Proposed measurements

Experiment: Low Energy Photoproduction

Cornell and SLAC:



SLAC:

Double Arm: published

Single arm: unpublished

large errors <12 GeV

σ: SLAC≈ Cornell

$\frac{d\sigma}{dt} = A \cdot \exp Bt$

E_γ GeV	11.	19
B $(GeV)^{-2}$	1.13±0.18	2.9±0.3

Indication: a slow decrease of cross-section towards the threshold

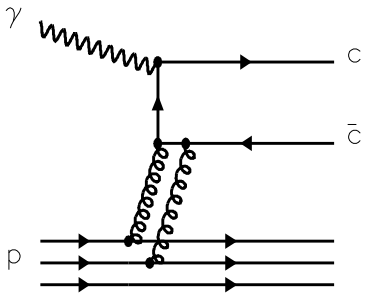
Production near threshold

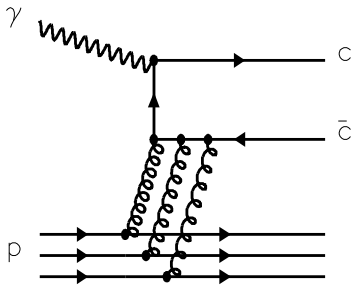
Should probe the particle distributions at high x.

Several constituents from the target should take part.

No detailed calculation exists so far.

Qualitative arguments on $\sigma(E_\gamma)$ (S.Brodsky, J.-M. Laget):

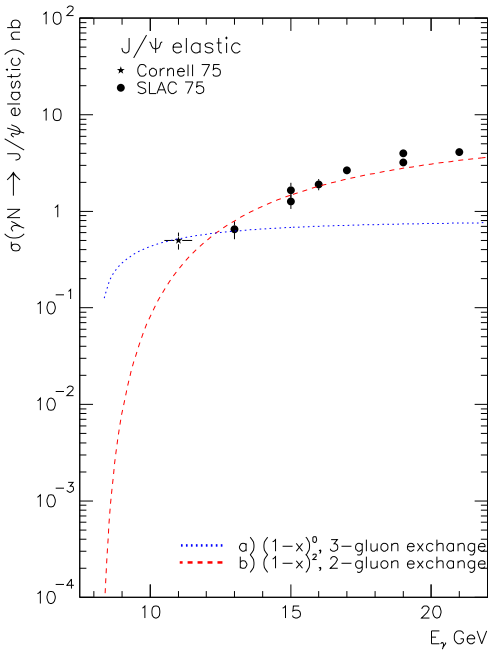




$$\frac{d\sigma}{dt} =$$

$$\mathcal{N}_{2g} v \frac{(1-x)^2}{R^2 \mathcal{M}^2} F_1(\tfrac{t}{4})(s-m_p^2)^2 \qquad \mathcal{N}_{3g} v \frac{(1-x)^0}{R^4 \mathcal{M}^4} F_1(\tfrac{t}{9})(s-m_p^2)^2$$

where: $x = \frac{s_{thresh}-m_p^2}{s-m_p^2}$, $\mathcal{M} = 2\, m_c$, $R \approx 1/m_c$



– applicable at $x \sim 1 \Rightarrow$ $E_\gamma < 12 - 15 GeV$

– fit to 2 low energy points

– Calling for rigorous calculations (GPD?)

ψN interactions

ψN interactions: attention from theorists

Practical interest: QGP

Features:

- small color dipole interacting with nuclear matter
- breakup by excitation to $D\overline{D}$ $\Delta E \sim 0.6\ GeV$
- possible loss due to $\psi + N \rightarrow \Lambda_c^+ \overline{D}$ at $P_\psi > 1.8\ GeV/c$

At low energy:

- attractive potential (Van der Waals)
  (Luke,Manohar,Savage,1992)
- $\sigma(\psi N)_{tot} \sim 7$ mb (Bordsky,Miller,1997), falling with energy

ΨN interactions

Experimental situation: confusing. Methods:

- From photoproduction, using VDM, optical theorem and assumptions on Re(A)/Im(A) (~ 0)
  - 20 GeV: $d\sigma(J/\psi \mathrm{N} \to J/\psi \mathrm{N})/dt \mid_{t=0} \sim 25\ \mu$b
  - 20-200 GeV: $\sigma(\mathrm{J}/\psi\mathrm{N})_{tot} \sim 1$ mb
- From A-dependence of photo and hadro-production, using Glauber model and considering color transparency effects at $\ell_{coh}, \ell_F > R_{target}$
  - 20 GeV γp: $\sigma(\mathrm{J}/\psi\mathrm{N})_{abs} \approx 3.5 \pm 0.8 \pm 0.6$ mb
  - 80-150 GeV hp: $\sigma(\mathrm{J}/\psi\mathrm{N})_{abs} \approx 7$ mb

Later corrections to the interpretations of the results:

- VDM: extended to a milti-channel case Hufner,Kopeliovich: $\sigma(\mathrm{J}/\psi\mathrm{N})_{tot} \sim 1$ mb $\Rightarrow$ 2.8 - 4.1 mb
- A-dependence: color transparency effects taken into account
  - 20 GeV γp: considered reliable
  - 80-150 GeV hp: $\sigma(\mathrm{J}/\psi\mathrm{N})_{abs} \sim 7$ mb $\Rightarrow$ 3.6 mb

Calculation of $\sigma(\psi N)_{tot}$ and ψ Photoproduction

(From: D.Kharzeev et al Eur.Phys.J. C 9,459 (1999))

Calculation of $\sigma(\psi N)_{tot}$ (rigorous in heavy quark limit):

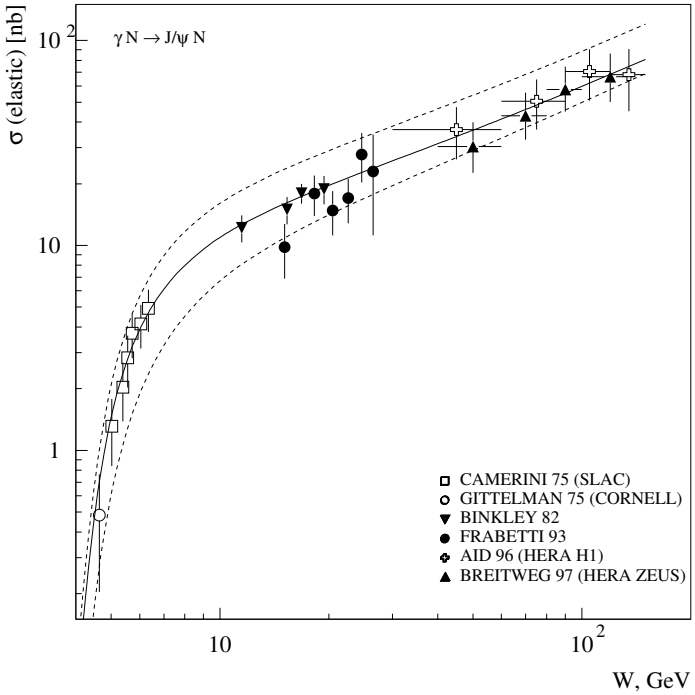
- short-distance QCD (similar to DIS)
- using gluon PDF of the nucleon

Is m_c large enough?

Test:

$\psi N \Rightarrow \gamma p \rightarrow \psi p$, using:

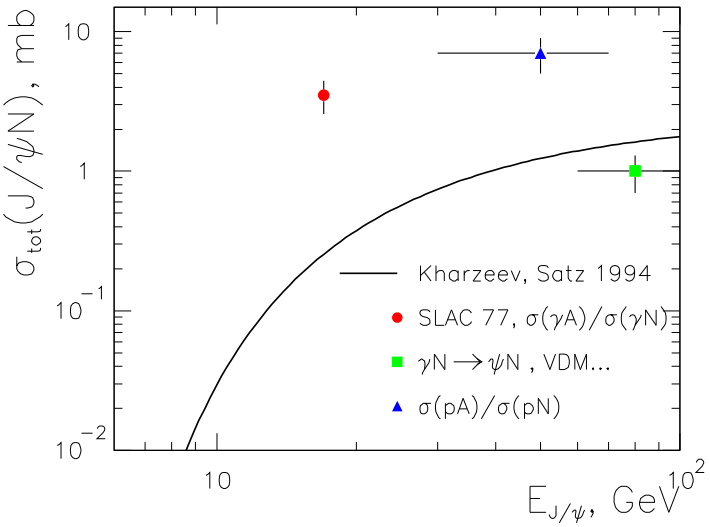
- VDM: E_γ >25 GeV
- optical theorem
- dispersion relations



Discrepancy at 17 GeV ×10

Fast drop at E<20 GeV

At E∼10 GeV - decisive



Program for JLab at 11 GeV

(1) Measure $\sigma(\mathrm{J}/\psi\mathrm{N})_{abs}$ using
A-dependence of $\sigma(\gamma\mathrm{A}\rightarrow\mathrm{J}/\psi\mathrm{X})$

Advantages comparing to the SLAC experiment:

- low background for $\mathrm{J}/\psi(1\mathrm{S})$
- reconstructed kinematics of $\mathrm{J}/\psi(1\mathrm{S})$
- separation of coherent and incoherent production
- lower energy - smaller effects from ℓ_{coh},ℓ_F
- several targets used

Disadvantages comparing to the SLAC experiment:

- lower energy - stronger effect from Fermi motion

New SLAC experiment E160 will start in 2004-2005. Still, the energy is about $\times 2$ of JLab. E140 and JLab are complimentary.

(2) Measure $\frac{d\sigma}{dt}(E)$ for $\gamma\mathrm{p}\rightarrow\mathrm{J}/\psi\mathrm{p}$

Goal:

- Provide Fermi-motion correction for (1)
- Measurement in a new energy range (3-gluon exchange?)

JLab standard spectrometers

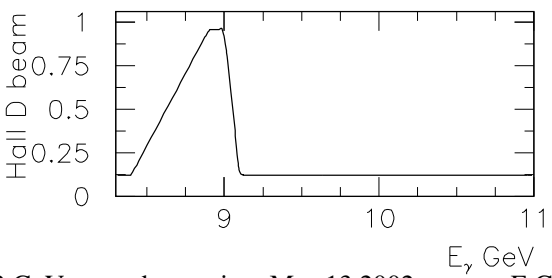
hall	beam	setup	$\Delta\Omega$	P_{max}	$\frac{\Delta P}{P}$	$\frac{\sigma P}{P}$	$\sigma\theta_{in}$	$\sigma\theta_{out}$
	μA		ster	GeV	%	%	mrad	mrad
Hall A	100	HRS	0.006	4.0	9	0.01	0.6	2.0
		HRS	0.006	3.2	9	0.01	0.6	2.0
		MAD*	0.030	6.0	15	0.3	1.0	2.0
Hall C	100	HMS	0.006	7.5	18	0.1	0.8	0.8
		SOS	0.009	1.8	40	0.1	1.0	1.0
		SHMS	0.003	12.	18	0.1	1.0	1.0
Hall B	0.01	CLAS	$\sim 2\pi$	-	-	0.5		
Hall D	γ		$\sim 4\pi$	-	-	<1.		

(*) Proposed for structure functions measurements

Possible photon flux:

- Halls A,C: $25\mu A$ at 6% RL radiator: $1.3 \cdot 10^{12}\gamma$/s/GeV on 15 cm LH
- Halls B: in $0.2 < \frac{E_\gamma}{E_0} < 0.95$: $< 10^7/10^8$ tagged/untagged
- Halls D, tagged:

  $\sim 2 \cdot 10^7/s$ in $8.4 < E_\gamma < 9.1$GeV coherent
  $\sim 2 \cdot 10^7/s$ in $8.4 < E_\gamma < 11.$GeV incoherent



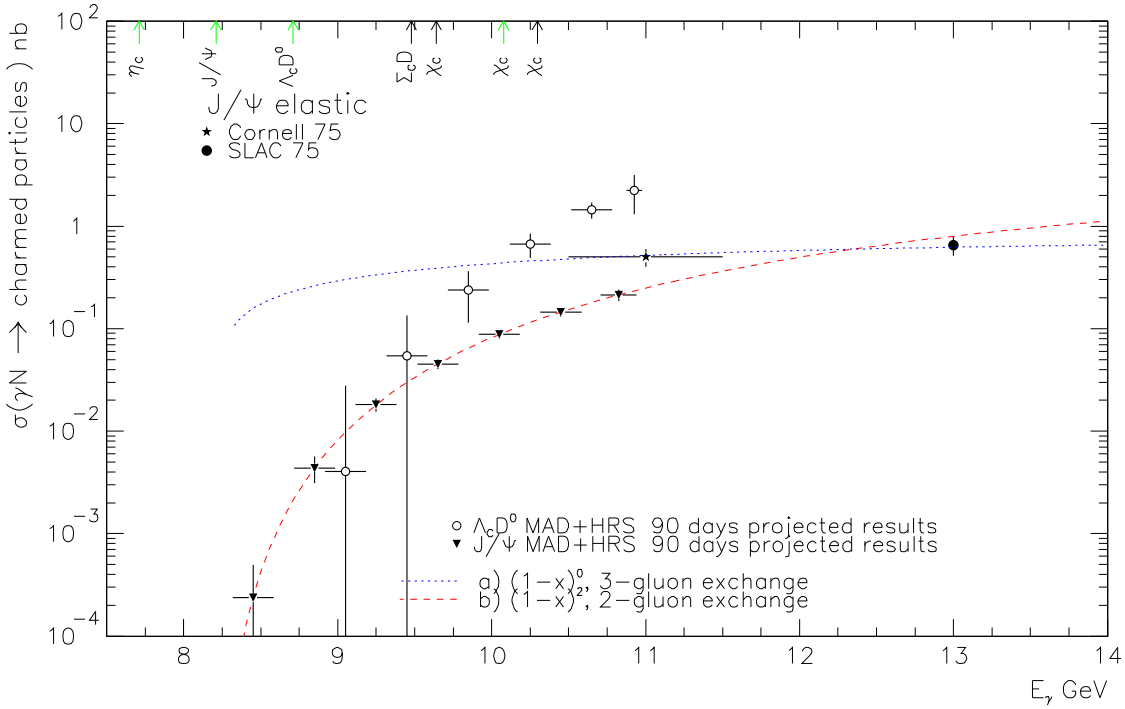
Standard spectrometers

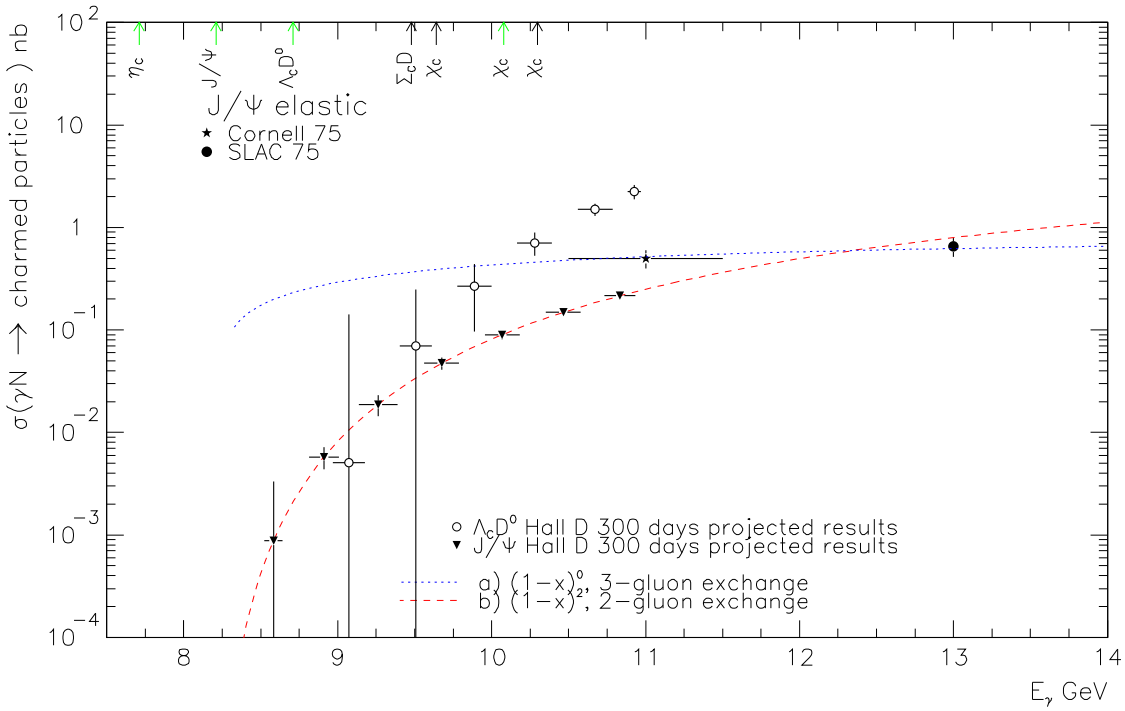
meaning		Hall D	HRS HRS	HRS MAD	HMS SOS	HMS SHMS
tagged γ		yes				
target LH		30 cm	15 cm	15 cm	4 cm	15 cm
$J/\psi(1S) \rightarrow e^+e^-, \mu^+\mu^-$						
$E_\gamma range$ GeV		8.3-11.	8.3-11.	8.3-11.	8.3-9.5	8.3-11.
decay angle CM		-	-	100°	51°	90°
Acceptance %		~ 40	-	0.027	0.026	0.009
$\sigma M/M$		$\sim 1\%$	-	0.24%	0.2%	0.2%
$(1-x)^2$	events/90days	260	-	2400	100	800
	days required*	640	-	190	-	560
$(1-x)^0$	events/90days	2100	-	28000	4100	9500
	days required*	40	-	45	-	130
$\overline{D}^0 \rightarrow K^+\pi^-$						
$E_\gamma$range GeV		8.7-9.3	8.7-11.	8.7-11.	8.7-10.	8.7-11.
decay angle CM		-	90°	100°	66°	80°
Acceptance %		~ 40	0.003	0.022	0.026	0.008
$\sigma M/M$		$\sim 1\%$	0.17%	0.2%	0.2%	0.2%
$(1-x)^2$	events/90days	540	400	2900	120	1100
$(1-x)^0$	events/90days	3400	13000	29000	4600	10000

* – Condition: the <error> at $E_\gamma - E_{thresh} > 0.4GeV$ is $< 10\%$

Hall A Charm Studies at 12GeV

Expected Results





$J/\psi(1S)$ on nuclear targets

- Hall D does not plan to use nuclear targets for the first stage.
- Hall A,C (say, MAD+HRS) can use nuclear targets for A-dependence measurements. No need to detect the recoil.

$\sigma_{\Psi N}$ can be derived from the A-dependence of the cross-section

R. Anderson, PRL38,263(1977)

J. Dunne, E. Ent, J.H. Mitchell and P.E. Bosted, LOI (1997)

J. Dunne, JLAB at 6-12 GeV Workshop (1998)

using nuclear models (Glauber model).

Assume for MAD+HRS:

- LH,LD 15 cm, with a 6%RL radiator
- Heavy targets of 7.7%RL ($\approx$ 6% radiator + LH target)
- For $J/\psi(1S)$ production $\sigma_A \approx A \cdot \sigma_N$
- End point of 11 GeV

target		^{1}H	^{2}H	Be	C	Al	Cu	Pb
$J/\psi(1S)$	$(1-x)^2$	160	320	550	360	210	110	60
/day	$(1-x)^0$	$\times$5.4						

1000 events per target: $\sim$ 50 days run

Extraction of $\sigma_{\psi N}$

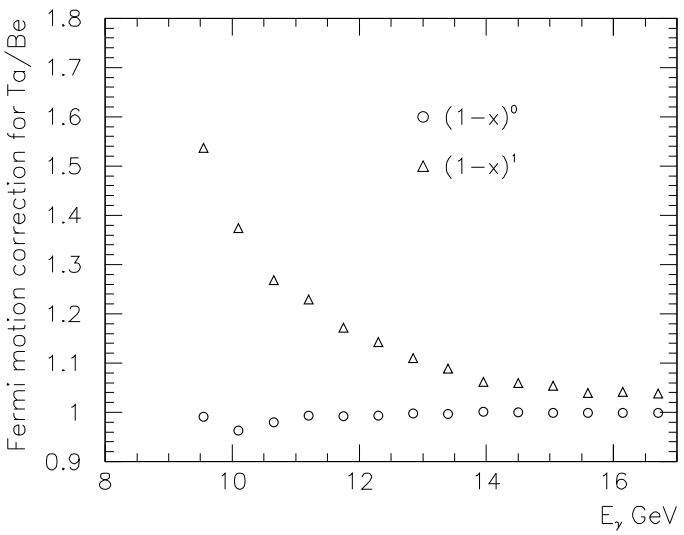
- Nuclear transparency: $T = \sigma_{\gamma A}/(A \cdot \sigma_{\gamma N})$

Same model as at SLAC: semi-classical eikonal approximation of nuclear re-scattering

Assumed: statistical error for each target 3%

$\sigma_{\psi N}$		A						$\sigma(\sigma_{\psi N})$
mb		9	12	27	63	108	207	mb
T	1.0	0.982	0.980	0.974	0.963	0.952	0.929	0.28
	3.5	0.938	0.931	0.908	0.870	0.833	0.751	0.24
	7.0	0.876	0.863	0.816	0.740	0.665	0.502	0.17

- Fermi-motion correction.



Conclusion

At 12 GeV JLab is capable of using $c\bar{c}$ as a probe of nuclear matter
Several measurements are proposed:

(1) Measurements of ψ-Nucleon cross-section. The expected errors are about 10% statistical and 15% systematic. This measurements are aiming to test if there is a considerable gluonic potential between colorless states. This cross-section has also been of a considerable interest for heavy ion physics.

(2) Measurements of $\frac{d\sigma}{dt}(E_\gamma)$ of $J/\psi(1S)$ is needed in order to fulfill (1). It is also of independent interest, probing compact, coherent states of valence quarks.

Experimental possibilities:

- The part (1) MAD+HRS in 2 months
- The part (2) MAD+HRS in 3 months

The part (2) on $J/\psi(1S)$ can be measured also by Hall D in about 2 years.