SLAC EXPERIMENT E160: A-DEPENDENCE OF J/ψ AND ψ' PHOTOPRODUCTION

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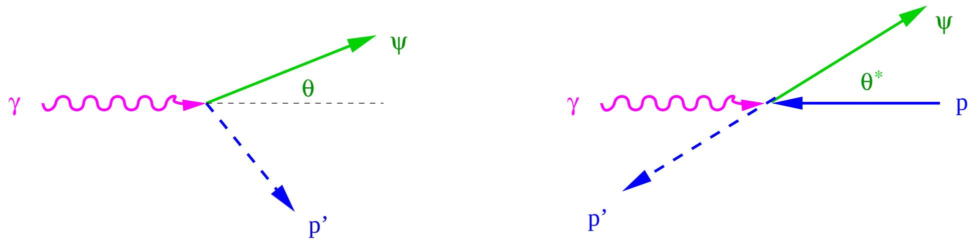
Representing the E160 Collaboration

Hall A 12 GeV Upgrade Workshop
22 March 2002

- Summary of J/ψ physics
- Summary of E160 experiment

Kinematics

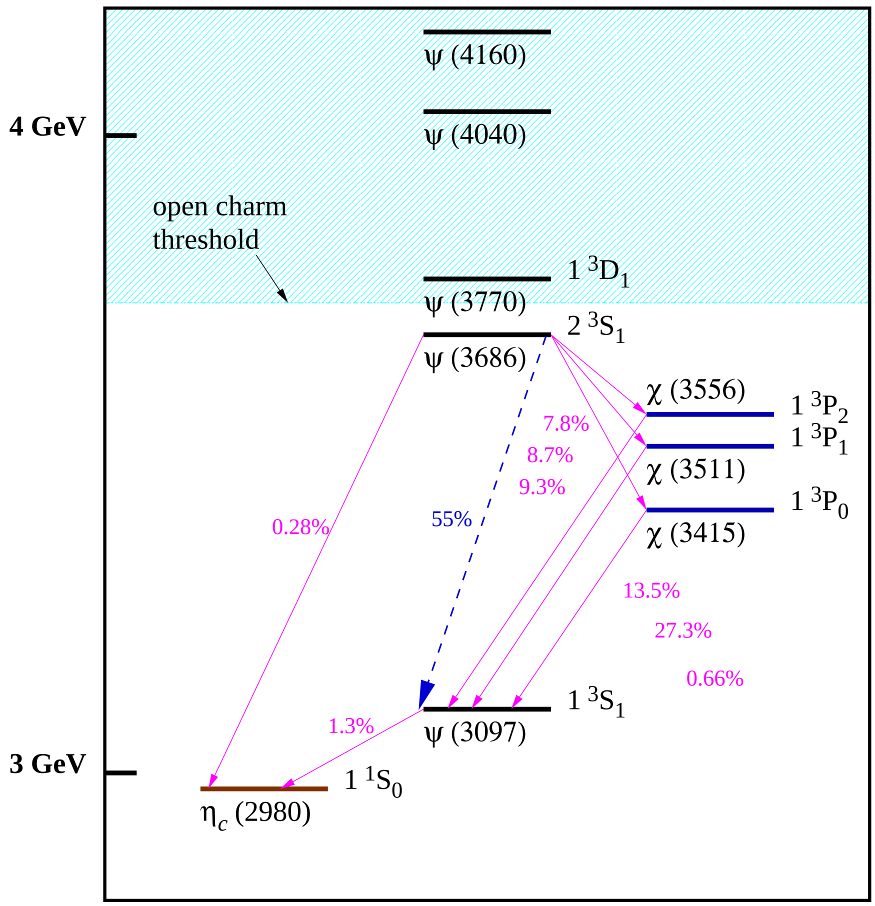


lab frame CM frame

particle	lab frame
γ	$(k, 0, 0, k)$
p	$(M, 0, 0, 0)$
ψ	$(E_\psi, k' \sin\theta, 0, k' \cos\theta)$
p'	$(k + M - E_\psi, -k' \sin\theta, 0, k - k' \cos\theta)$
particle	**CM**
γ	$(k^*, 0, 0, k^*)$
p	$(\sqrt{M^2 + k^{*2}}, 0, 0, -k^*)$
ψ	$(E_\psi^*, k'^* \sin\theta^*, 0, k'^* \cos\theta^*)$
p'	$(\sqrt{M^2 + k'^{*2}}, -k'^* \sin\theta^*, 0, -k'^* \cos\theta^*)$

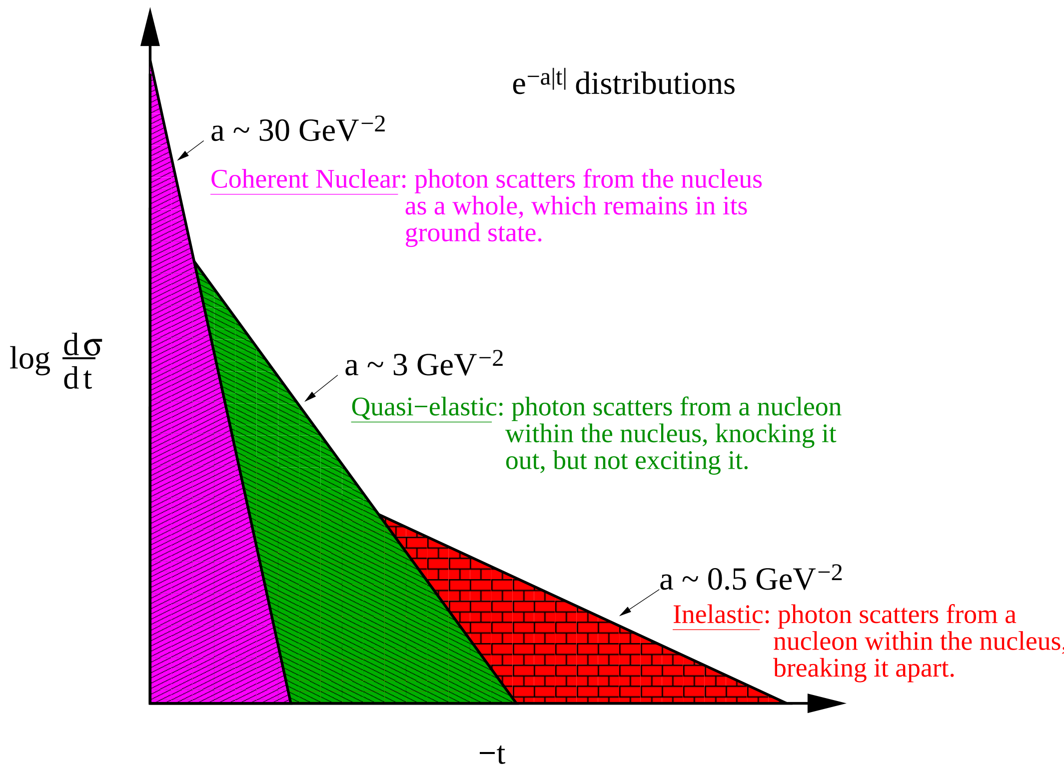
- $s = M^2 + 2Mk$ is the CM energy squared.
- $t = m_\psi^2 - 2k(E_\psi - k' \cos\theta)$ is the squared 4-momentum transfer.
- $p_T^2 = (k'^* \sin\theta^*)^2$ is the transverse momentum squared.

Charmonium States



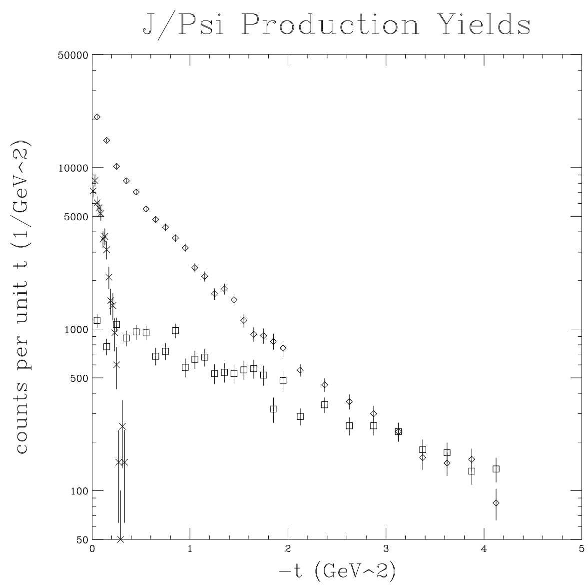
- Shaded region shows the continuum for decays into open charm ($D\bar{D}$) states.
- Photons excite $J^{\pi} = 1^{-}$ states ($e.g.$ $^{3}S_{1}$).

Schematic J/ψ t-Distributions



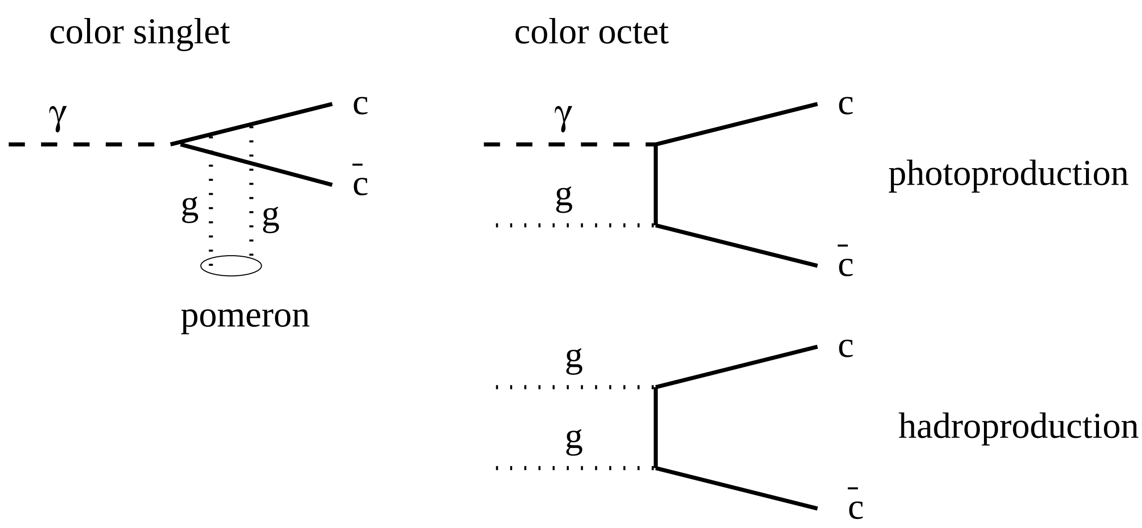
- size of nucleus (nucleon) $\sim 1/\sqrt{\langle t \rangle} \sim \sqrt{a}$
- Coherent nuclear and quasi-elastic: vector meson dominance, pomeron exchange, diffractive processes.
- Inelastic: photon-gluon fusion.

Physics Model (con't)



- Simulated t distribution for J/ψ production
  - counts per GeV^2 vs. t
  - t-resolution of 0.1 GeV^2
  - 8000 quasi-elastic events
  - 1000 coherent events (x)
  - 2000 inelastic events (squares)
  - total events shown as diamonds

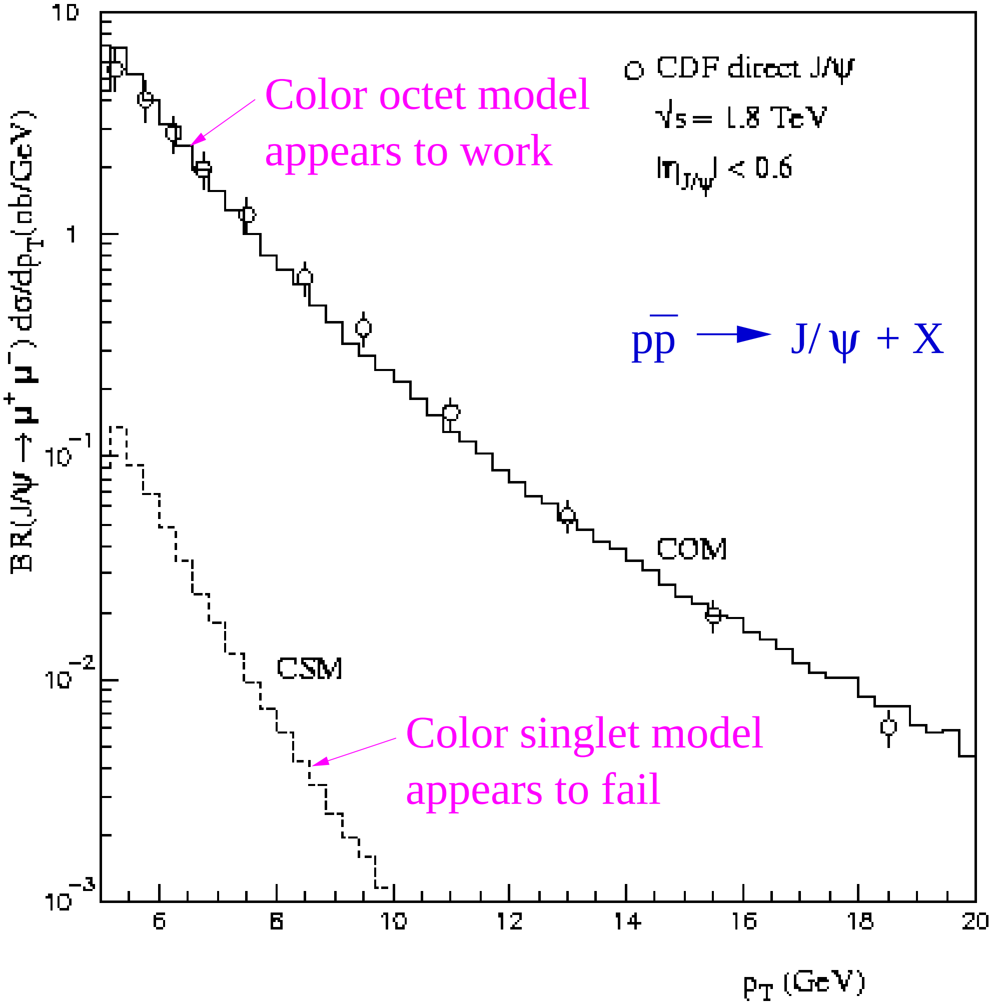
Motivation



- Charmonium production: perturbative interactions, non-perturbative formation.
- Cross sections: perturbative $\rightarrow$ kinematic dependence; non-perturbative $\rightarrow$ incalculable magnitude.
- No direct evidence for correct perturbative diagrams (e.g. photoproduction explained by both color singlet and octet models).
- Charmonium-nucleon interaction cross sections are not well known or understood.
- Yet charmonium production is used to probe gluon distributions and hot nuclear matter.

Paradox of Charmonium Production I

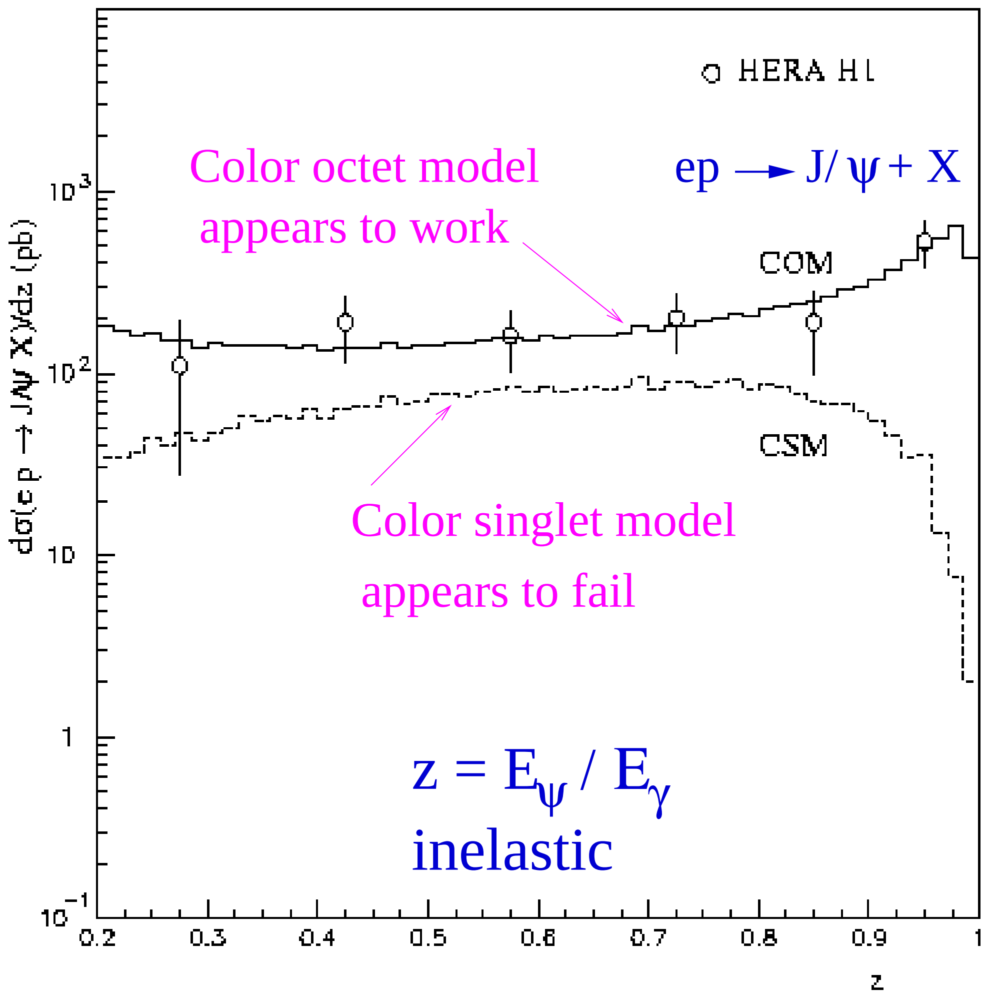
J.K. Mizukoshi, hepph9911384



- CDF Collaboration, F. Abe, *et al.*, Phys. Rev. Lett. **69**(1992)3704; **79**(1997)572; **79**(1997)578.

Paradox of Charmonium Production II

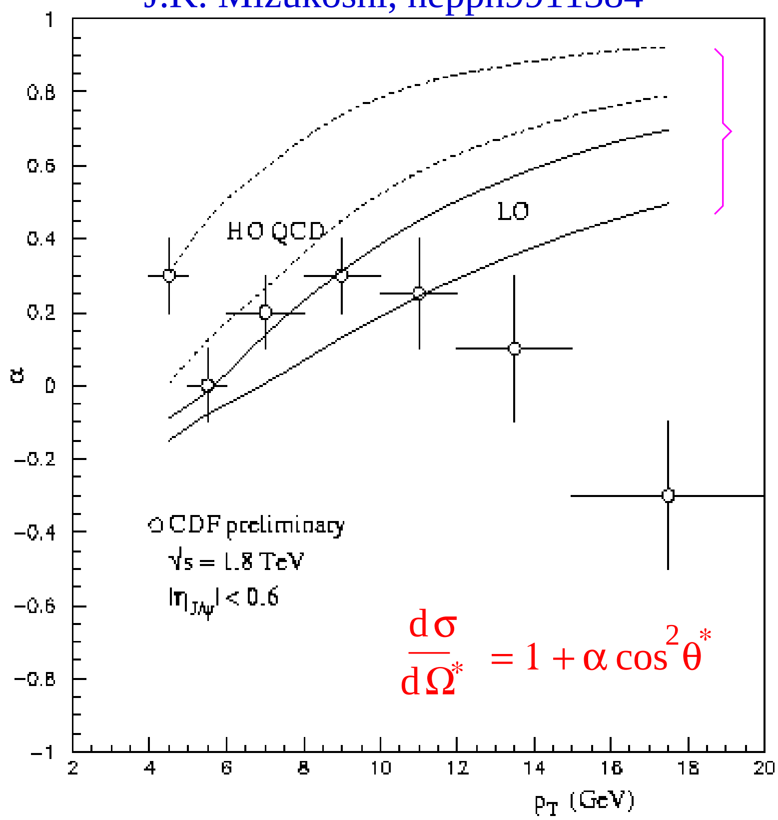
J.K. Mizukoshi, hepph9911384



- H1 Collab., S. Aid, *et al.*, Nucl. Phys. **B472**(1996)3.

Paradox of Charmonium Production III

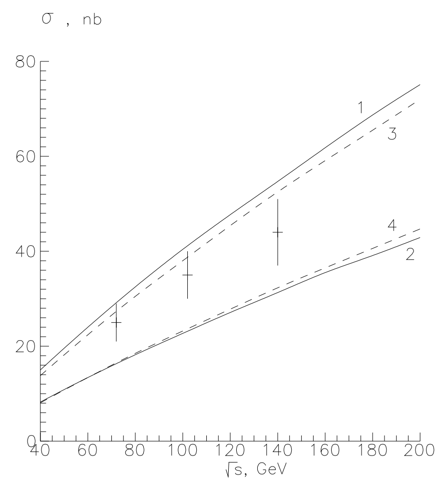
J.K. Mizukoshi, hepph9911384

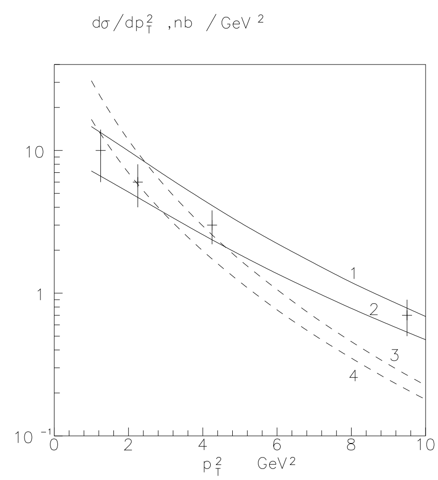


Color octet model appears to fail.

- CDF Collaboration

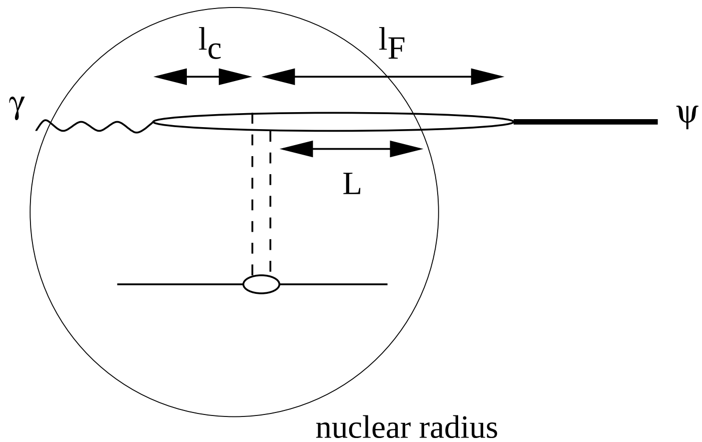
Color Singlet Model with k_T

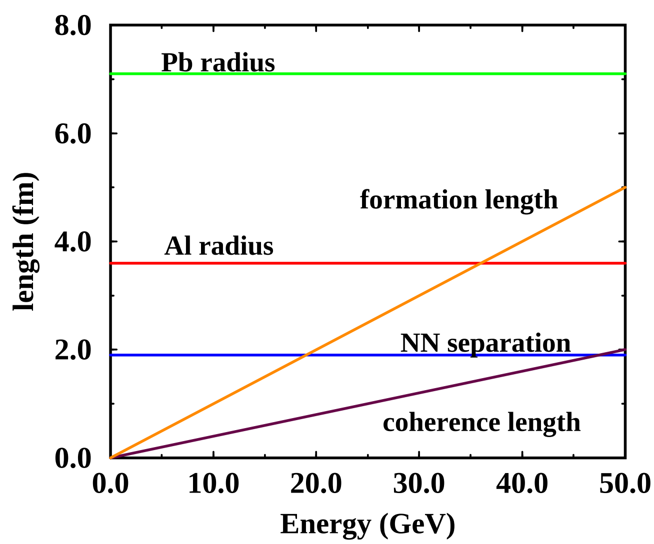




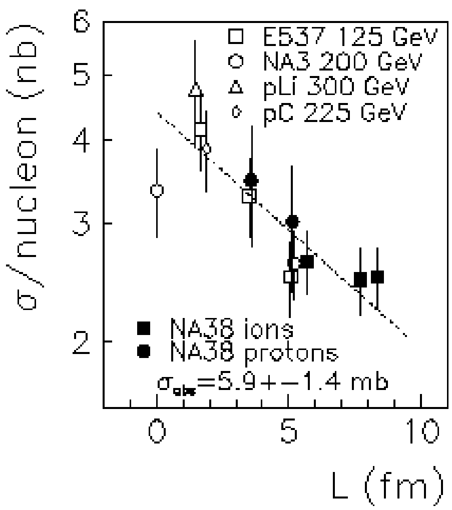
- Inelastic ($0.4 < z < 0.9$) J/ψ photoproduction with $p_T > 1$ GeV. Curves 1,2 (3,4): k_T-factorization (parton model) for $m_c = 1.4$ and 1.55 GeV. Saleev, hepph-0201027.

Length Scales





$\psi - N$ Cross Sections

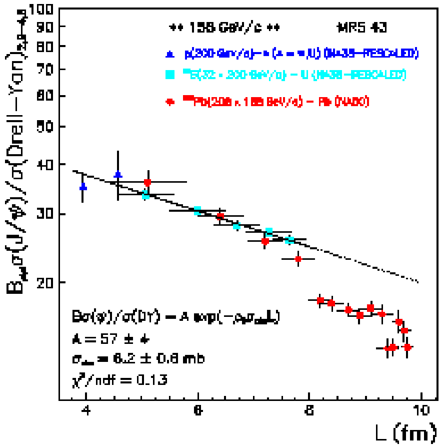


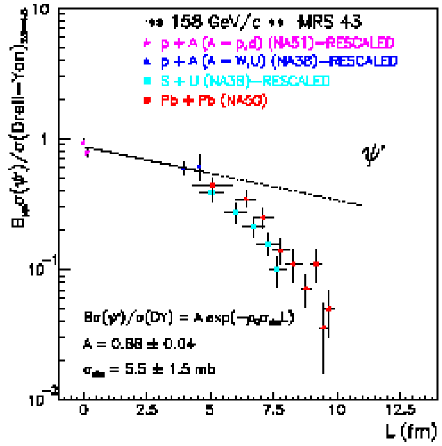
- Data: nucl-th/9806023 review
- Glauber:

$$\frac{\sigma^{pA\to\psi}}{A\sigma^{pN\to\psi}} = e^{-L\rho_0\sigma_{\rm tot}^{\psi N}}.$$

  in which L is the length of absorption trajectory, ρ_0 is nuclear density. If $L \propto A^{\frac{1}{3}}$ then $\sigma_{\rm tot}^{\psi N} \propto A^{\alpha}$. $\sigma_{\rm tot}^{\psi N} \approx 6$ mb, $\alpha \approx 0.92$.
- Vector Meson Dominance: $\sigma_{\rm tot}^{\psi N} \propto \frac{d\sigma}{dt}(\gamma N \to \psi N)|_{t=0}$ by the optical theorem. $\sigma_{\rm tot}^{\psi N} \leq 1$ mb.
- Geometry: $\sigma_{\rm tot}^{\psi N}$ is proportional to the square radius. $\sigma_{\rm tot}^{\psi N} = 2 - 5$ mb.

J/ψ Suppression for Heavy Ions





- From B. Müller, nucl-th/980623:
- It's still unclear whether J/ψ is a reliable probe for quark-gluon plasmas.
- Suppression in light targets is the result of the $A^{0.92}$ dependence of the $pA \to J/\psi X$ cross section.
- The color octet model provides a credible mechanism, but there is no direct evidence for it.
- Available evidence points toward a novel suppression in Pb+Pb collisions.
- Color singlet absorption on hadronic comovers does not explain the Pb+Pb data.

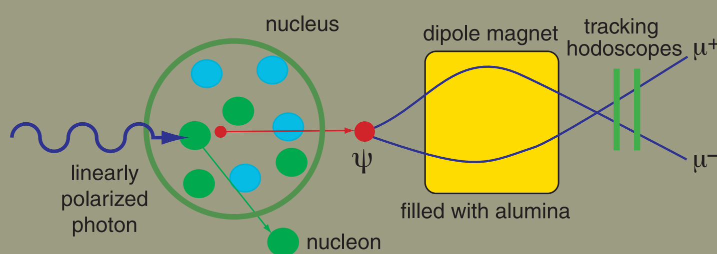
E160

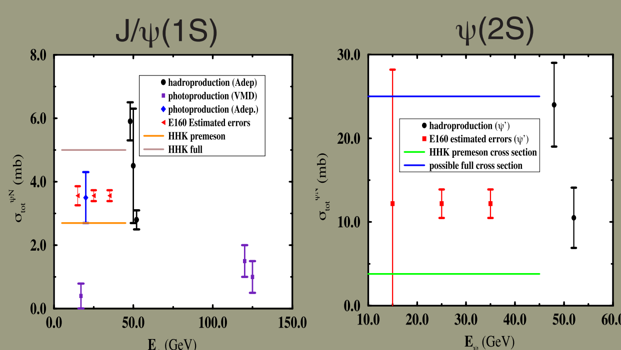
Measurement of the A-Dependence of J/ψ(1S) and ψ(2S) Photoproduction

Goals

1) Study production and interaction of charmonium in nuclei from Be to Au at energies from 15 to 35 GeV.

2) Constrain causes for charmonium suppression in heavy ion collisions.





Projected Errors

www.slac.stanford.edu/exp/e160

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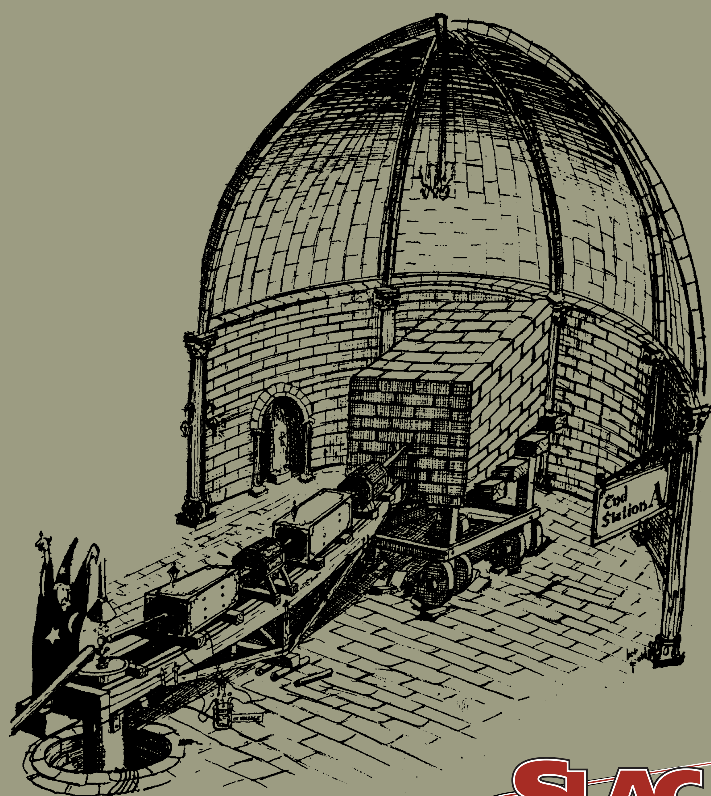
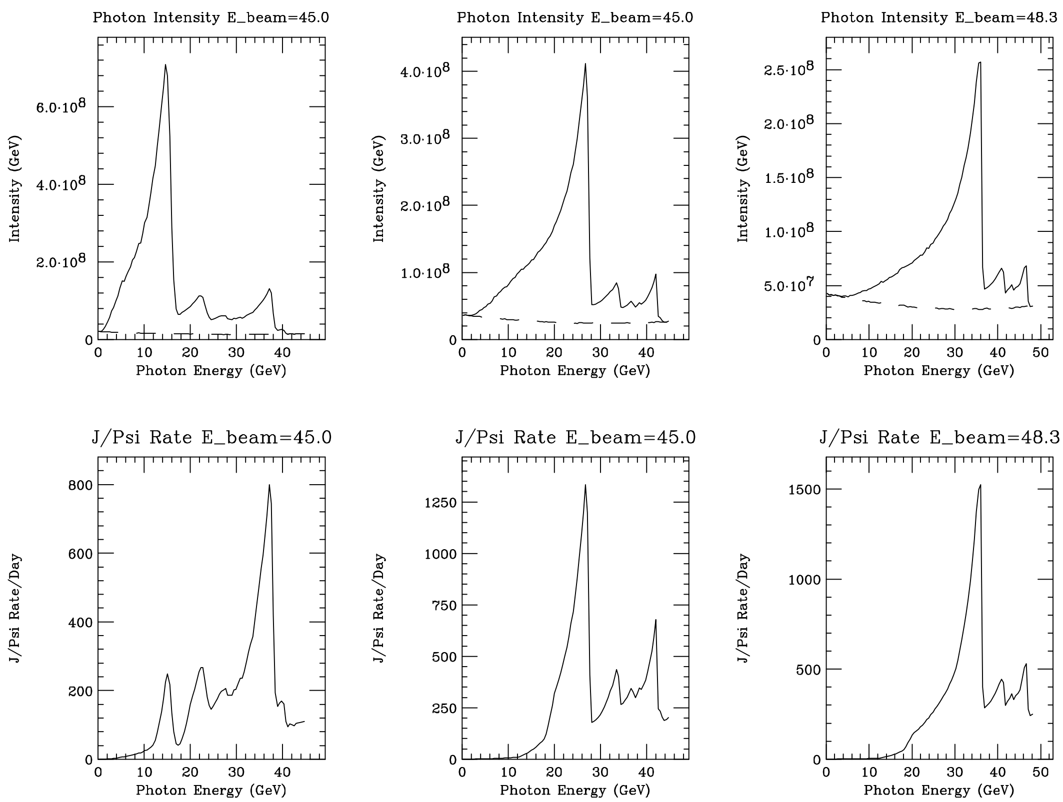
END STATION A



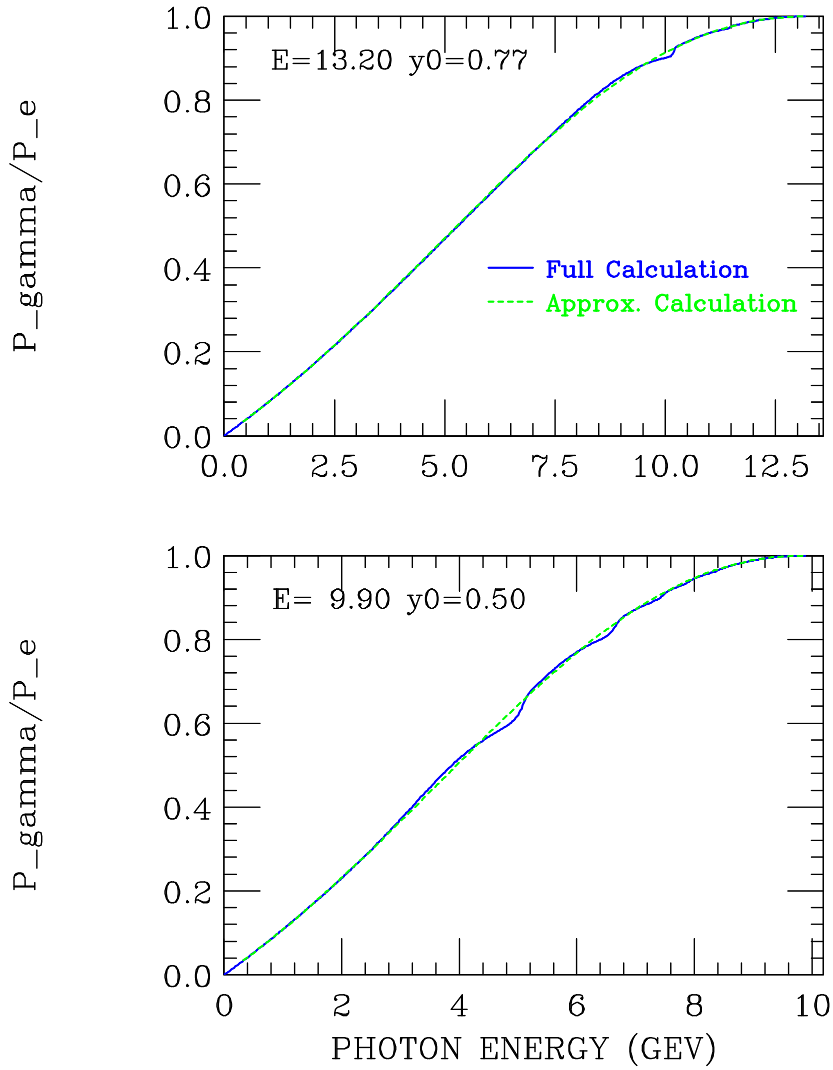
SLAC

Beam Intensity and Rates



- Electron beam energies: 45.0, 45.0 and 48.3 GeV.
- Upper: photon intensities (flux times energy).
- Dashed lines: incoherent radiation.
- Lower: quasi-elastic J/ψ events per day for a 1 g/cm^2 thick target.

Circular Polarization



$P_\gamma^{\text{linear}} \sim 1 - y; \qquad y = E_\gamma / E_e$

Conclusions

- E160 will study J/ψ and ψ' production and propagation through nuclei with error bars small enough to make a difference for interpretations of J/ψ suppression in relativistic heavy-ion collisions. This suppression remains one of the most promising indicators of quark-gluon plasma formation.
- E160 will measure fundamental charmonium cross sections $d\sigma/dt$ and $\sigma_{\rm tot}^{\psi N}$ with at least a factor of three improvement in accuracy over an energy range where one would be surprised not to find large variations produced by ℓ_F.
- E160 will provide data using a simple probe, the results of which are easier to interpret than hadron-induced reactions.
- E160 will make the first ever measurement of the A-dependence of ψ' photoproduction and test the claim that $\sigma_{\rm tot}^{\psi' N}$ is as large as 25 mb.
- E160 will constrain models for the creation and interaction of J/ψ and ψ' particles, and shed light on the VMD mystery.