# Cross-Section Curve Fits for $J/\psi$ Photoproduction: Quasi-Elastic Case

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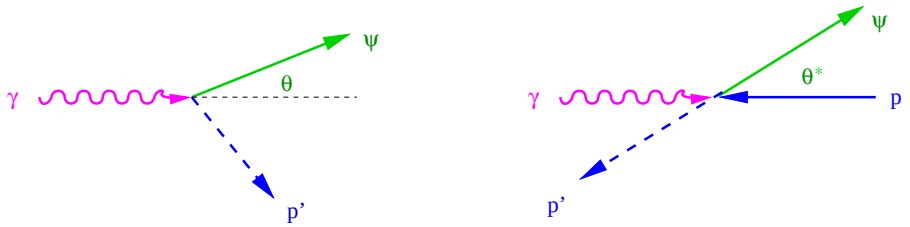
$J/\psi$ Photoproduction: LAB vs. CM frames




lab frame CM frame

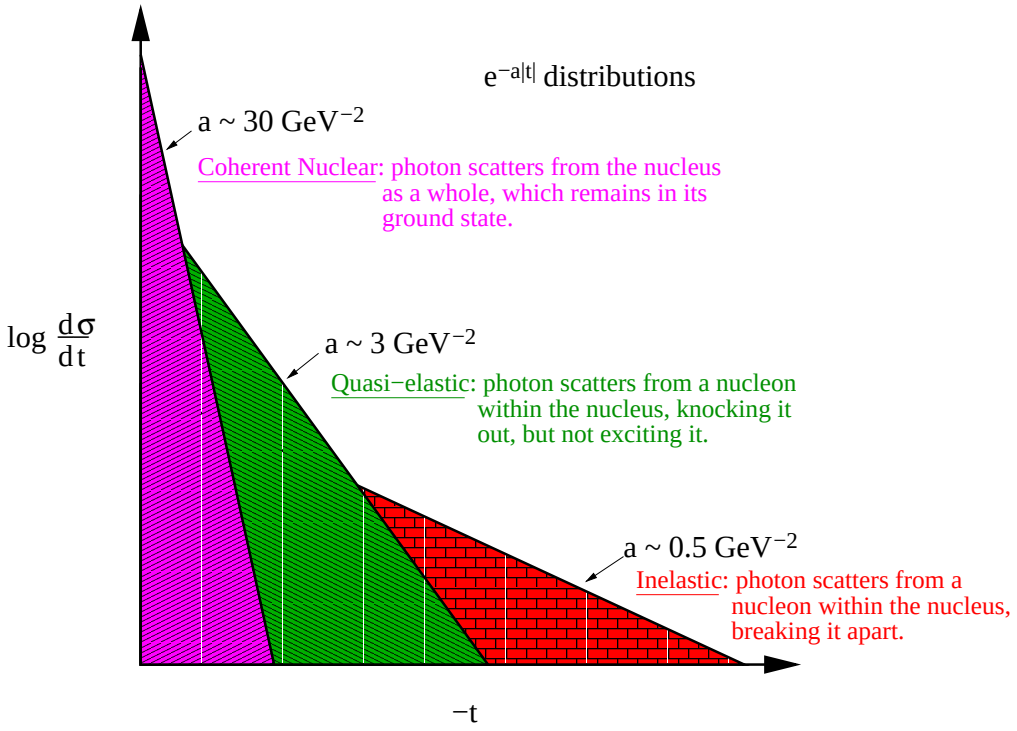
• W is the total collision energy measured in the CM frame.

$$W = \sqrt{2E_\gamma m_p + {m_p}^2}$$

where $m_p \equiv$ proton mass ( $\sim 938$MeV)

and $E_\gamma \equiv$ incident photon energy in lab frame

• Cross-sections and slope parameters for $J/\psi$ photoproduction were plotted as a function of W.




• $d\sigma/dt$ is a measurable quantity, from which total-cross section $\sigma$ can be calculated by integration.

$$d\sigma/dt = Ae^{-b|t|}$$

$t \equiv$ 4-momentum transfer in collision

$b \equiv a \equiv$ slope fit parameter; determined experimentally

• $b$ tends to be inversely related to target size; $\therefore$ $b$ is lowest for coherent scattering; larger for individual nucleon scattering.

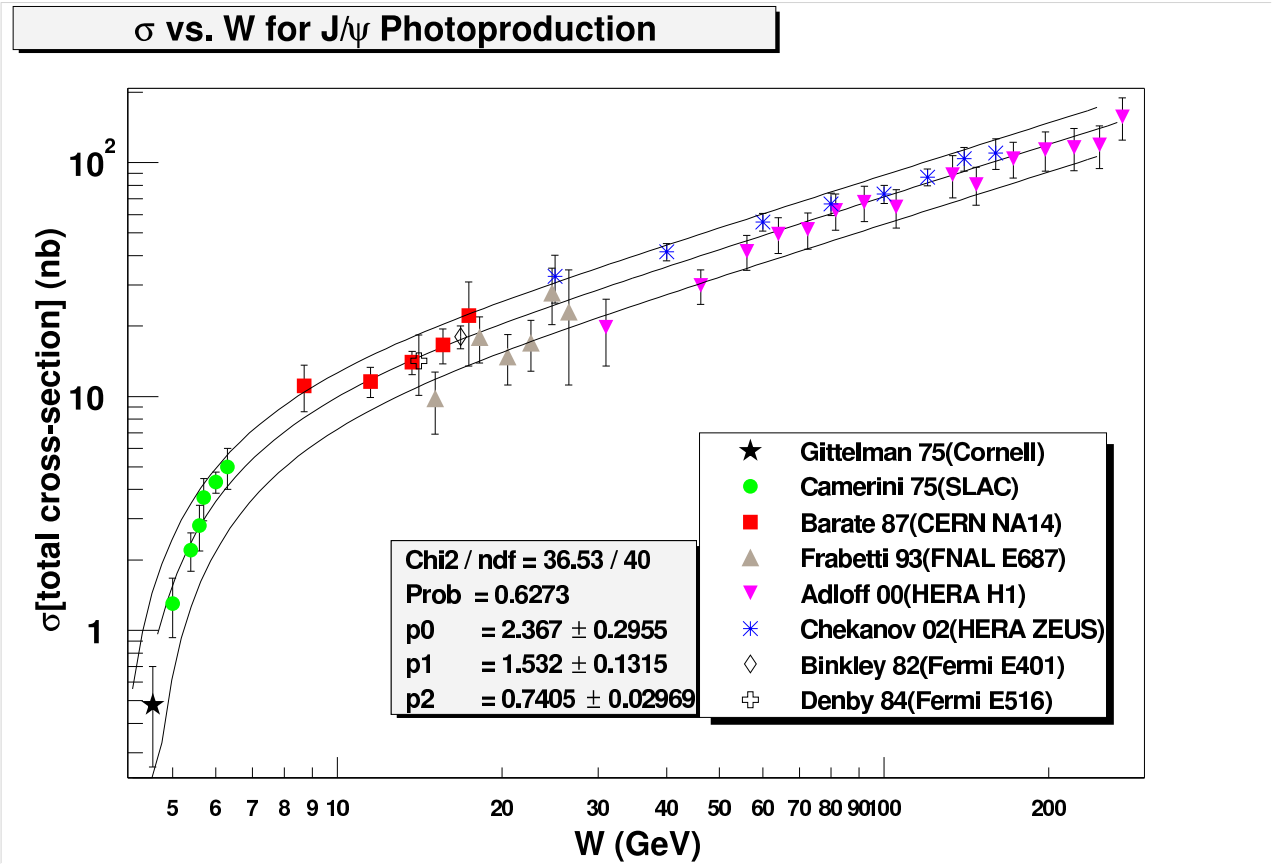
Calculation of $\sigma$ by integration:

$$\frac{d\sigma}{dt} = Ae^{-b|t|} \tag{1}$$

$$\sigma = \int_{|t_{min}|}^{\infty} \frac{d\sigma}{dt} dt = \int_{|t_{min}|}^{\infty} Ae^{-b|t|} dt \tag{2}$$

$$\sigma = -\frac{Ae^{-b|t|}}{b}\Big|_{|t_{min}|}^{\infty} \tag{3}$$

$$\sigma = \frac{Ae^{-b|t_{min}|}}{b} \tag{4}$$




- $\sigma$ vs. $W$ fit is given by

$$\sigma = \alpha_1 \cdot (1 - \frac{W_{th}^2}{W^2})^{\alpha_2} \cdot W^{\alpha_3}$$

- The data fits well with the theoretical curve. ($\chi^2 \approx 0.9$)
- $W_{th}$ is the photoproduction threshold energy (4.0 GeV in the CM frame).
- $\alpha_1$, $\alpha_2$, $\alpha_3$ are fit parameters determined by the ROOT program. ($\alpha_1 = 2.367$, $\alpha_2 = 1.532$, $\alpha_3 = 0.7405$)

• The equation for $\sigma$ was differentiated implicitly with respect to each $\alpha$ and added in quadrature to give the resultant error range:

$$\frac{d\sigma}{\sigma} = \sqrt{(\frac{d\alpha_1}{\alpha_1})^2 + \left[\frac{\alpha_2 d\alpha_2}{(1 - \frac{W_{th}^2}{W^2})}\right]^2 + (\frac{\alpha_3}{W} d\alpha_3)^2}$$

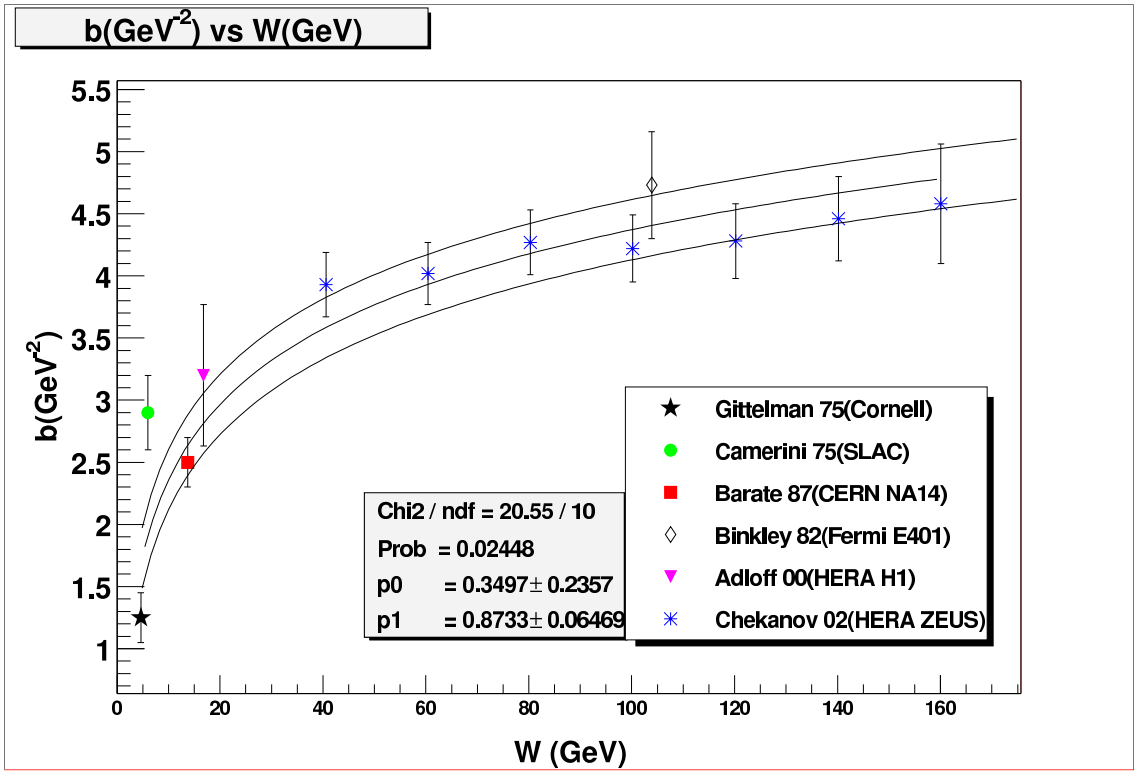
• Data from the various source publications was not always easy to interpret!

– Data from early sources (Gittelman '75, Camerini '75) provided only $d\sigma/dt$, data on $t$, $t_min$ was scattered throughout the literature and difficult to locate; $\sigma$ was calculated using

$$\sigma = \frac{d\sigma/dt}{be^{t-t_{min}}}$$

– One source (Barate '87) did not have any numeric data for $\sigma$ or $d\sigma/dt$ values at all; the points and their error bars had to be interpolated from a graph.

– More recent papers (particularly those using data from HERA) were much better organized (i.e. included values of $\sigma$, $W$, $E_\gamma$ and error ranges.)




- $\sigma$ vs. $W$ fit is given by

$$b = b_0 + b_1 \ln W$$

- Error range determined by

$$\frac{db}{b} = \sqrt{db_0^2 + (\ln W db_1)^2}$$

- $b$ appears to fall in the quasielastic range ($\sim$3 GeV$^{-2}$)
- Data for $b$ was difficult to extract; weighted values were calculated from each source (except for Chekanov '02 at HERA).
- The poor value for chi-squared ($\chi^2 \approx 2.1$) makes apparent a need for a better theoretical fit or more complete data.

## Conclusions:

- The relation

$$\sigma = \alpha_1 \cdot (1 - \frac{W_{th}^2}{W^2})^{\alpha_2} \cdot W^{\alpha_3}$$

provides a good fit for total cross-section vs. total energy (CM frame) for quasi-elastic $J/\psi$ photoproduction.

- The relation

$$b = b_0 + b_1 lnW$$

does not provide a good fit to the available data, establishing a need for a better curve fit and/or data, especially at lower energies.

- The E160 experiment should provide more accurate data for energies near the threshold energy (i.e. $W \equiv$ 5-10 GeV).

- The importance of presenting data ($\sigma$, $W$, $b$, $d\sigma/dt$) in organized tabular form cannot be overemphasized!