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A measurement of the σ_{ep}, for $Q^2 < 0.3$ GeV^2, as a by-product of the F_2 measurement.

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Abstract

An indirect measurement of the total cross section σ_{ep}, in the region of $Q^2 < 0.3$ GeV^2 and $y > 0.6$, is given using the '95 shifted vertex data. This measurement is found to be in agreement with the recent ALLM97 parametrisation.

1 Introduction

One of the main problems in the physics analysis is that of isolate the reaction of interest from all other processes which produce the same effects on the detectors, and which are therefore indistinguishable on an event-by-event basis. The quality of the results depends them on the understanding of the background and any uncertainty on it will be reflected on the quantities of interest. In the case of the F_2 analysis at low x and Q^2 the main source of background is due to photoproduction in which a fake scattered electron is reconstracted by the analysis algoritm.

The usual way of handling background is to substract from the observed number of events a certain fraction which correspond to the its expected number. This is done in each cell of the measured x and Q^2. The F_2 analysis of the '95 Shifted Vertex Data described in [1] and [2] follows a different approach, in which the observed events are assigned, with suited probabilities, to the signal and to the background. The result is a global inference on both processes, performed, technically, by the so called unfolding. The probabilities with which the events are assigned to each physical *cause* are evaluated by *probability inversion*, i.e. starting from the probability of observing those data given a certain cause [3]. The results on F_2 obtained by this method have been shown in [1] and [2]. In this note I concentrate the attention on the measurement of the total hadronic *ep* cross section in the photoproduction regime which comes as a by-product of the primary analysis. This result is then compared with theoretical predictions.

2 Bayes' unfolding - short recap

The measurement of the F_2 structure function is equivalent to the measurement of the differential cross section $\frac{d^2\sigma}{dydQ^2}$. Therefore, we need to unfold the measured distribution to get the ("true") number of the events in the selected bins.

Known the $P(E_j|C_i)$, the likelihood that effect E_j (an observed event reconstructed in the bin j) is due to cause C_i, and $n(E_j)$, the measured number of events in the bin j, the unfolded number of events due to the C_i is given by:

$$\hat{n}(C_i) = \frac{1}{\epsilon_i} \sum_j n(E_j) P(C_i|E_j) \tag{1}$$

where $\epsilon_i = \sum_{j=1}^{n_E} P(E_j|C_i)$ is the efficiency of detecting an event generated by C_i. The elements $P(C_i|E_j)$ are calculated by the Bayes' theorem:

$$P(C_i|E_j) = \frac{P(E_j|C_i)P_o(C_i)}{\sum_{i=1}^{n_C} P(E_j|C_i)P_o(C_i)} \tag{2}$$

3 The extraction of the total cross section σ_{ep}

The *ep* cross section σ_{ep} can be viewed as the product of the flux of virtual photon times total cross section of photon proton scattering:

$$\sigma_{ep}(Q^2 < Q^2_{max}; y_{min} < y < y_{max}) = \int\int dydQ^2 \sigma_{\gamma^* p}(Q^2, W)\phi(Q^2, y) \tag{3}$$

where

$$\phi(Q^2, y) = \frac{\alpha_{em}}{2\pi} \frac{1}{yQ^2} \left[1 + (1-y)^2 - 2\frac{m_e^2 y^2}{Q^2} \right] \tag{4}$$

is the flux of virtual photon.

3.1 The $C(PhP)$

One of the cause that contributes to the F_2 measurement is the so called photoproduction background, generated according the 3 in the low Q^2 regime (the average value is $\sim 10^{-5}$). This cause is included in the unfolding procedure. Therefore if N were the selected bins to extract the F_2 values, the all cause's cells are now $N + 1$.

But Bayes' theorem requires the knowledge of initial probability $P_o(\mathbf{C})$. These $P_o(\mathbf{C})$ represents the relative normalisation among the different causes, so they should be chosen in agreement with the cross section for each cause [1].

The initial value is estimated by Monte Carlo simulation based on PYTHIA [4], with the MRSA [5] structure function. The used sample corresponds to an integrated luminosity $\mathcal{L}_{php} = 253.1\ \text{nb}^{-1}$.

At this level we are in the same condition of the standard method: we use as input value the number given by the Monte Carlo, the same value that are subtracted in the standard approach.

Anyway, this is just an initial condition, after the unfolding, in fact, we get the ("true") $P_o(\mathbf{C})$ according to the data. This is the reason why the Bayes unfolding allows to infer from the data not only the F_2 values but also important informations related to the background sources.

3.2 Evaluation of the $P(\mathbf{E}|\mathbf{C})$

The $P(\mathbf{E}|\mathbf{C})$ characterises the shape of the background and it depends critically on the type of the interaction mechanism. The crucial point for this unfolding procedure is the evaluation of the element $P(\mathbf{E}|\mathbf{C})$.

The implicit assumption that MC simulates well the interaction mechanism is, however, well justified from the experimental data as shown, for example, in figure 1.

3.3 The cross section value with only Type A uncertainties

The analysed data sample corresponds to a luminosity $\mathcal{L}_{data} = 236.5\ \text{nb}^{-1}$. From the unfolding procedure we get:

$$N_{PhP} = (231.5 \pm 2.0) \cdot 10^3 \tag{6}$$

that means, translated into a cross section:

$$\sigma_{ep} = 0.979 \pm 0.008 \quad \mu b \tag{7}$$

with a $Q^2_{max} = 0.3\ \text{GeV}^2$ and $y > 0.6$, given by the generated photoproduction Monte Carlo events.

3.4 Systematics check: evaluation of type B uncertainties.

The method used in this analysis to evaluate the uncertainties due to the systematic effects is the same as described in [6]. For more details on the systematic studies used here refer to [1].

[1] Let suppose to have 3 causes, and let be N_1,N_2 and N_3 the generated number of events, with the luminosity L_1,L_2 and L_3, respectively. The initial probability can be chosen in the following way, normalised to the data, for example:

$$N_{tot} = \mathcal{L}_{data} \sum_i \frac{N_i}{\mathcal{L}_i} \;\rightarrow\; 1 = \frac{N_{tot}}{N_{tot}} = \sum_i \frac{N_i}{\mathcal{L}_i} \frac{\mathcal{L}_{data}}{N_{tot}} = \sum_i P_o(C_i) \tag{5}$$

Just to remind how the systematics checks are considered, let be μ_o the value obtained with the (nominal) systematic hypothesis h_o. The corrected μ can be expressed as a function of μ_o and of a shift g due to the systematic effect $\mathbf{h}$.

$$\mu = \mu_o + g(\mathbf{h}) \tag{8}$$

The best value of μ and its variance is, using a Taylor's expansion at the first order:

$$\hat{\mu} = E[\mu] \sim \mu_o + E[\sum_l \frac{\partial g}{\partial h_l}(h_l - h_{ol})] \equiv \mu_o + \sum_l \delta\mu_l \tag{9}$$

$$\sigma^2 = \sigma_o^2 + \sum_l \left(\frac{\partial g}{\partial h_l}\right)^2 \sigma_{h_l}^2 \equiv \sigma_o^2 + \sum_l u_l^2 \tag{10}$$

The contributions given by each systematic source are reported in the table 1. From the table 1 we get:

$$N_{PhP} = (232 \pm 17) \cdot 10^3 \tag{11}$$

that means

$$\sigma_{ep} = 0.980 \pm 0.073 \quad \mu b \tag{12}$$

3.5 Comparison to the theory

In order to see if this number is meaningful, we compare it, for example, with the value given by the ALLM97 parametrisation [7], that includes the new low x and low Q^2 HERA data.

The theoretical value is

$$\sigma_{ep}^{ALLM}(Q^2 < 0.3; y > 0.6) = 0.989 \;\; \mu b. \tag{13}$$

The result is in agreement with the extracted cross section. It is important to stress that even if this analysis can, in principle, improve the knowledge of the σ_{ep} one has to notice that the experimental result has to be taken with some care. For example, it depends critically on the shape of the background assumed and a more refined study should be performed.

4 Conclusions

The probabilistic unfolding procedure gives us the possibility to extract the total cross section σ_{ep} from the F_2 analisys, obtaining values in agreement with the recent estimates from the ALLM97 parametrisation. This is also a different way to check the F_2 analysis' self-consistency.

h_l		$\mu_l \cdot 10^{-3}$		$\delta\mu_l \cdot 10^{-3}$	$u_l \cdot 10^{-3}$
1	positron energy scale	$+1\sigma$	232.1	-0.76	1.3
		-1σ	229.4		
2	hadron energy scale	$+1\sigma$	235.4	-0.28	4.7
		-1σ	226.5		
3	X position	$+1\sigma$	231.3	-0.12	0.05
		-1σ	231.4		
4	Y position	$+1\sigma$	231.1	-0.30	0.1
		-1σ	231.3		
5	F_L	$+1\sigma$	231.5	0.0	0.0
		-1σ	231.5		
6	vertex position	$+1\sigma$	231.7	-0.01	0.2
		-1σ	231.3		
7	Php efficiencies	$+1\sigma$	217.2	1.59	15.9
		-1σ	248.9		
8	Beam gas	$+1\sigma$	230.1	0.10	1.5
		-1σ	233.0		
9	$E - P_z$ cut	$+1\sigma$	228.6	0.62	3.5
		-1σ	235.7		
10	y_{JB}	$+1\sigma$	230.6	-0.60	0.3
		-1σ	231.2		
				0.24	17.0
Nominal analisys: $\mu_0 \pm u_0$				$(231.5 \pm 2.0) \cdot 10^3$	
Final result: $\mu_f \pm u_f$				$(232 \pm 17) \cdot 10^3$	

Table 1: *In the table are reported the deviations on the unfolded number of events due to the different systematic studies. In addition is shown the result obtained in the nominal analisys and the corrected one.*

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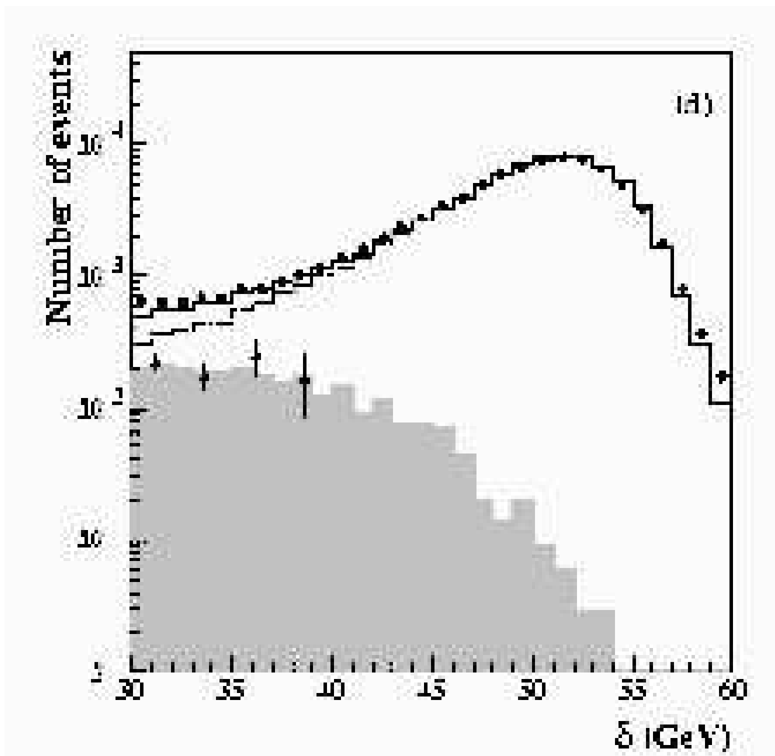

Figure 1: *$E - P_z$ distribution. The data (dots) are compared to the MC simulation. Photoproduction background estimated by MC simulation (hatched histogram) is also shown. In addition the measured photoproduction events are shown as filled triangles.*

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