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Change to the DØ Luminosity Monitor Constant

N. Amos et al.

Fermi National Accelerator Laboratory
P.O. Box 500, Batavia, Illinois 60510

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N.Amos, J.Bantly, A.Brandt, R.Demina, A.Goldschmidt
R.Partridge, L.Paterno, D.Puseljic, J.Thompson

DØ Luminosity Working Group

Abstract

The DØ experiment has previously calculated its luminosities using a visible cross section (luminosity monitor constant) for its Level Ø trigger, $\sigma_{L\emptyset} = 42.9$ mb based on the E710 inelastic cross section measurements. Recently, CDF has also published inelastic cross section measurements markedly different from E710. The DØ experiment has moved to world average inelastic cross sections at $\sqrt{s} = 1.8$ TeV. The result changes the DØ visible cross section to $\sigma_{L\emptyset} = 48.2$ mb which is an increase of 12.4% in the visible cross section value. The error on luminosity has been left unchanged at 12%.

1 Introduction

DØ cross sections quoted and published prior to the summer of 1994 used a measure of luminosity [1] based on measurements by E710 [2] of the total, elastic, and single diffractive $\bar{p}$-p cross sections at $\sqrt{s} = 1.8$ TeV and with an error of 12%. CDF has recently published its own measurements of these three cross sections [3] [4] [5]. The DØ experiment has decided to adopt the 'world average' values for the total, elastic, and single diffractive cross sections. The decision to adopt a 'world average' at $\sqrt{s} = 1.8$ TeV leads to a recalculation of the DØ luminosity monitor constant, $\sigma_{L\emptyset}$. Further, since the CDF and E710 experiments results are not in close agreement, a review of both analyses was made. The input data and the recalculation for $\sigma_{L\emptyset}$ are given below.

2 The Level Ø Trigger

The Level Ø (LØ) trigger [6] is a fast triggering system for the DØ detector. With a beam crossing occurring every 3.5μs, the Level Ø trigger indicates which beam crossings contain non-diffractive inelastic collisions and monitors the instantaneous luminosity. The LØ detector is comprised of two hodoscope scintillator arrays located on the inside faces of the DØ detector's two end-cap calorimeters, 140 cm from the center of the detector. Each array partially covers a region in pseudorapidity of $1.9 < |\eta| < 4.3$, with nearly complete coverage over $2.2 < |\eta| < 3.9$. The pseudorapidity coverage is motivated by the requirement that a coincidence of both Level Ø arrays be $\geq 99\%$ efficient in detecting non-diffractive inelastic collisions. In addition, the Level Ø trigger provides fast measurements of the interaction position along the beam axis for use in early trigger decisions.

3 Instantaneous Luminosity based on LØ Scaler Rates

The instantaneous luminosity $\mathcal{L}$ is simply related to the counting rate $R_{L\emptyset}$ in the Level Ø counters by:

$$\mathcal{L} = \frac{R_{L\emptyset}}{\sigma_{L\emptyset}} \tag{1}$$

where $\sigma_{L\emptyset}$ is the cross section subtended by these counters (see next section). The instantaneous luminosity and counting rate are treated separately for each of the six bunch crossing combinations.

This is, of course, only strictly true if the instantaneous luminosity is low enough that the counting rate corresponds to the interaction rate. As the luminosity increases, there is the possibility for having multiple interactions in a single crossing. For this case, the counting rate is less than the interaction rate since multiple interactions get counted only once.

The multiple interaction correction may be calculated based on Poisson statistics. The average number of interactions per crossing, $\bar{n}$, is given by:

$$\bar{n} = \mathcal{L}\ \tau\ \sigma_{\mathrm{L}\emptyset} \tag{2}$$

where τ is the crossing time ($\tau = 3.5\ \mu s$). The multiples correction factor is then just:

$$\frac{\mathcal{L}}{\mathcal{L}_{\mathrm{meas}}} = \frac{\bar{n}}{1 - e^{-\bar{n}}} = \frac{-\ln(1 - \mathcal{L}_{\mathrm{meas}}\ \tau\ \sigma_{\mathrm{L}\emptyset})}{\mathcal{L}_{\mathrm{meas}}\ \tau\ \sigma_{\mathrm{L}\emptyset}} \tag{3}$$

4 Calculation of the LØ Monitor Constant

All cross sections come from the E710 [2] and CDF [3] [4] [5] measurements of the total, elastic and single diffractive cross sections. The components of the calculation for the monitor constant, $\sigma_{\mathrm{L}\emptyset}$, are summarized in Table 1 below, and the error estimates are given in Table 2 below. Several notes regarding this calculation follow:

- Because of the large differences reported between the two experiments in the measured cross sections, the error on the inelastic cross section, $\sigma_{inelastic}$, has been scaled by χ taken from the χ^2 of the probability that the two values, within errors, are the same.

- The average multiplicities of charged particles in the Level Ø fast sum counters were taken from the MBR Monte Carlo (Appendix B of Ref. [5]) with the Level Ø geometry and may somewhat underestimate the efficiency since the Monte Carlo does not include photon conversions or detector simulation. This has the largest effect on ϵ_{SD} to which the LØ trigger is least sensitive.

- The inelastic cross section ($\sigma_{inelastic}$) includes hard core (ϵ_{HC}), single diffractive (σ_{SD}), and double diffractive (σ_{DD}) scatterings. The fraction of HC+DD that was double diffractive (f_{DD}) was assumed to be 10±10%. The DD fraction was obtained from an MBR study and the 100% error is arbitrarily assigned.

- The HC and DD efficiencies, ϵ_{HC} and ϵ_{DD}, were calculated assuming Poisson statistics and a requirement of greater than zero hits in both

	Mean	Error
CDF Inelastic Cross Section	60.33 mb	1.4 mb
CDF SD Cross Section	9.46 mb	0.44 mb
E710 Inelastic Cross Section	55.5 mb	2.2 mb
E710 SD (SA) Cross Section	11.7 mb	2.3 mb
Avg Inelastic Cross Section	58.9 mb	1.2 mb
Avg SD Cross Section	9.5 mb	0.4 mb
Inelastic Cross Section χ^2	3.4307	
SD Cross Section χ^2	0.915	
Inelastic Error Scale Factor χ	1.8522	
SD Error Scale Factor	1.0	
Inelastic Cross Section ($\sigma_{inelastic}$)	58.938 mb	2.1877 mb
SD Cross Section (σ_{SD})	9.5391 mb	0.4322 mb
HC + DD Cross Section	49.4 mb	2.2 mb
DD Fraction of HC+DD (f_{DD})	0.1	0.1
Average HC Multiplicity	5.4	–
Average DD Multiplicity	2.5	–
HC Efficiency (ϵ_{HC})	99%	1%
DD Efficiency (ϵ_{DD})	84%	10%
SD Efficiency (ϵ_{SD})	5%	5%
Level Ø Efficiency ($\epsilon_{\mathrm{L}\emptyset}$)	99%	1%
Observable Cross Section	48.2 mb	2.5 mb

Table 1: Luminosity Counter Cross Section Calculation

DD Fraction Error	0.7 mb
Inelastic Cross Section Error	2.1 mb
SD Cross Section Error	0.4 mb
HC Efficiency Error	0.4 mb
DD Efficiency Error	0.5 mb
SD Efficiency Error	0.5 mb
Level Ø Efficiency Error	0.5 mb
Total Cross Section Error	2.5 mb

Table 2: Luminosity Counter Cross Section Error Analysis

Level Ø counter arrays. The SD efficiency, ϵ_{SD}, was taken to be 5±5% obtained from an MBR study and the 100% error is arbitrarily assigned.

- The vertex position cut implicit in using the fast vertex module for counting luminosity is approximately a cut at 3 standard deviations in the interaction z distribution at DØ. The cut is at $|z| <$96.875cm and the LØ inefficiency was assumed to be 1±1%.
- The E710 single arm (SA) cross section was used for the E710 single diffractive result as it more closely represented the physics signal seen by the LØ trigger than the more recent E710 single diffractive result [7].

The calculation of $\sigma_{L\emptyset}$ is given in Equation 4.

$$\sigma_{L\emptyset} = \epsilon_{L\emptyset}(\epsilon_{SD}\sigma_{SD} + \epsilon_{DD}f_{DD}(\sigma_{inelastic} - \sigma_{SD}) + \epsilon_{HC}(1 - f_{DD})(\sigma_{inelastic} - \sigma_{SD})) \quad (4)$$

where $\epsilon_{L\emptyset}$ is the efficiency for the LØ trigger vertex cut efficiency. The efficiency and all of the remaining quantities are listed in Table 1.

5 Conclusions

The observable cross section for the Level Ø counters is $\sigma_{L\emptyset}$=48.2 mb when using the world average for the total, elastic, and single diffractive cross sections. This is a 12.4% increase over the previous value of 42.9 mb and hence reduces the $\int \mathcal{L}dt$ of a given data set. A preliminary error on $\sigma_{L\emptyset}$ is indicated in Table 2. However, we have kept the error on the luminosity at 12% at this time because of concerns about correlated errors. Additional studies are being carried out that include full detector simulation and use other event generators.

References

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