# DØ Luminosity in Run 2: Triggered

Michael Begel,[3] Dan Edmunds,[2] Philipe Laurens,[2] Richard Partridge[1]

[1] *Brown University, Providence, Rhode Island*
[2] *Michigan State University, Michigan*
[3] *University of Rochester, Rochester, New York*

May 23, 2003

The philosophy behind the measurement and propagation of luminosity information at DØ imposes constraints upon normalized physics analyses. This note, one of a series on basic luminosity concepts, describes how DØ measures the triggered luminosity at Level 1. Additionally, the Luminosity Block Number is defined and the concept of Exposure Group is presented.

## 1 Introduction

The role of the Luminosity ID group is to measure, record, and provide normalization information appropriate for DØ physics analyses, provide feedback on beam conditions to DØ Operations and Beams Division, and report on luminosity and operations to the DØ leadership and the Fermilab Directorate. This document describes the methodology used to determine the luminosity triggered by DØ. Other documents in this series describe the measurement of delivered luminosity [1], recorded luminosity [2], and other details of the detector, electronics, and data acquisition systems [3].

## 2 Trigger Framework

Level 1 (L1) is a hardware trigger system consisting of the L1 Trigger Framework (TFW) [4] and the L1 trigger subsystems (Fig. 1). Each subsystem processes detector-specific information and sends, every 132 ns (every tick), its results to the TFW via And/Or terms (AOT) [5]. AOT are used to include physics, beam, background, or environmental information needed to form a trigger decision. Each AOT is a binary signal captured by the TFW every tick and can either be asserted or negated. There are 256 available AOT.

A L1 trigger is defined by a set of AOT. All 128 L1 triggers are evaluated every tick. The TFW determines for each L1 trigger whether the resulting event should be rejected or

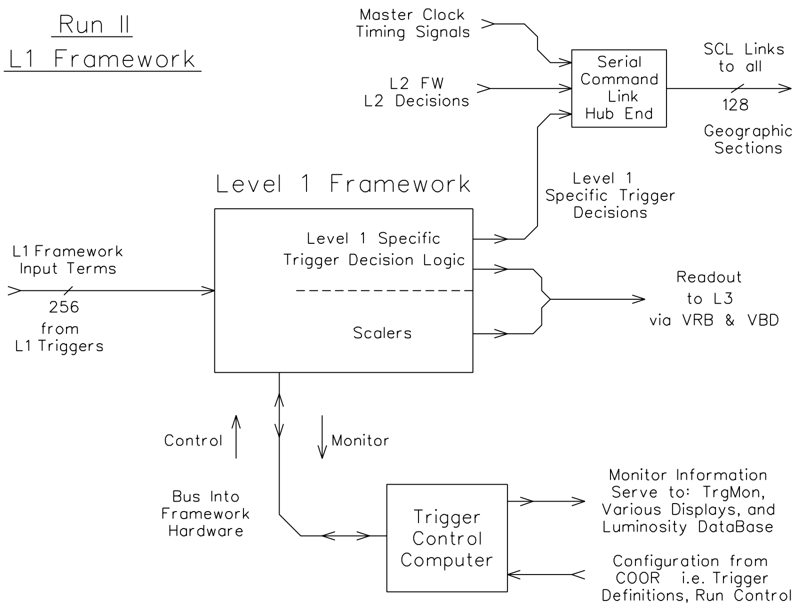


Figure 1: Block diagram of the Trigger Framework showing its connections to the data acquisition system.

captured for further analysis by L2 using the AOT and other information about the readiness of the DAQ. The global L1 decision is the logical OR of these decisions.

All parts of the DAQ that capture data in response to L1 accepts and send this data to L3 are connected to the TFW by a Serial Command Link (SCL). Each of these DAQ components is called a Geographic Section (GS). The SCL is a two-way communication link where the TFW tells the GS which ticks to capture (L1 accept), and where the GS tells the TFW when it is not in a state to accept additional events (i.e. front-end busy or error signals). This control path carries a lot of other information, for example, timing and L2 decision information. The TFW supports 128 GS. Typical GS are detector front-ends, but other subsystems also contribute data to the event.

The TFW is programmed and controlled by the Trigger Control Computer (TCC). TCC receives high-level programming requests from COOR, the global coordinating program for the online system, and performs the low-level register programming operations required to implement COOR's requests [6]. Each of the 128 L1 triggers can be independently enabled or disabled by COOR at anytime.

# 3 Luminosity Block Number

The luminosity block is the fundamental unit of time for luminosity measurement. Each block is indexed by a unique 32-bit integer, the luminosity block number (LBN), which monotonically increases throughout Run 2. (LBN and luminosity block tend to be used interchangeably in the luminosity documentation and code.) The LBN is incremented if any of the following conditions are met:

1. on request (Trigger Framework, COOR, Luminosity DAQ),
2. a Trigger Framework init is issued,
3. a Serial Command Link init is issued,
4. a store transition occurs (begin, end),
5. a run transition occurs (start, stop, pause, resume),
6. an internal timer is satisfied (period is 60 seconds).

The time span was chosen based on numerous constraints in the luminosity, trigger, and DAQ systems. The time period is short enough so that the instantaneous luminosity is effectively constant during each luminosity block, introducing negligible uncertainty into the measurement of the luminosity due to the width of the time slice. The LBN is incremented on a TFW or SCL init since key scalers are reset. The LBN is incremented on run and store transitions to ensure that data within a luminosity block is subject to uniform conditions, i.e., that data taking doesn't stop part way through a measurement period.

# 4 Measuring Triggered Luminosity

The main concern in calculating the luminosity per L1 trigger is that the non-uniform bunch-to-bunch luminosity profile causes correlations in trigger response. For example, a given L1 trigger might have a higher probability of being satisfied for a crossing with high luminosity thus causing the data acquisition system to be disabled for the next few ticks. Additionally, some L1 triggers might be restricted to specific ticks. For example, jet triggers might only be allowed to fire on the first bunch of a superbunch since there is no pile-up of energy from preceeding crossings in the calorimeter.

The measurement of the luminosity appropriate for a particular L1 trigger is similar to that described in DØ Note 3970 [1]. The primary difference is that the measurement is limited to crossings when the trigger was capable of being satisfied. The delivered luminosity is defined by

$$\mathcal{L} = -\frac{f/159}{\sigma} \sum_{i=1}^{159} \ln\left(1 - \frac{\Delta LM_i}{\Delta ticks/159}\right), \tag{1}$$

where $f$ is the Tevatron revolution frequency (47.713 KHz), $\Delta LM_i$ is the scaler count from the Luminosity Monitor (LM) for tick $i$ during the luminosity block, $\sigma$ is the effective $p\bar{p}$ cross section for satisfying the LM coincidence, and $\Delta ticks$ is the length of the luminosity block in 132 ns ticks. Note that the delivered luminosity is calculated independently for each of the 159 ticks and summed.

The luminosity for each L1 trigger is formulated in the same fashion as Eq. 1. One useful observation is that the probability of an interaction in a given crossing ($159 \times \Delta LM_i/\Delta ticks$) does not change when we restrict the trigger's exposure to specific ticks (exposure is independent of the current crossing even though it may depend upon previous crossings). We define the luminosity of L1 trigger $n$ as

$$\mathcal{L}_{L1}(n) = -\frac{f/159}{\sigma}\sum_{i=1}^{159}\frac{\Delta L1\ exposed_{n,i}}{\Delta ticks/159}\ln\left(1-\frac{\Delta LM_i}{\Delta ticks/159}\right). \tag{2}$$

The problem with this formulation is the sheer number of scalers needed to collect this information. Aside from the scalers used by the LM, we would require 159 scalers (one per tick) for each of the 128 L1 triggers.

# 5 Exposure Group

The only way to reduce the number of scalers is to require that several triggers use the same scalers, that is, to group together triggers with common dead-time. This requires groups of triggers to have common sources of enable, disable, and readout. These groups are called Exposure Groups (EG) and eight have been implemented in the TFW [4, 7, 8]. L1 triggers belong to one, and only one, EG. **All L1 triggers within an EG have the same dead-time.** Every run with at least one L1 trigger must contain at least one EG. This limits us to eight simultaneous runs each with one EG, one run with eight EG, or any other legitimate combination. EG resources are managed by COOR and described within the trigger configuration [6].

Not all sources of enable and disable need be constrained to properly determine the luminosity. Sources of trigger enable and disable are judged according to their level of correlation with the bunch-to-bunch luminosity profile. One difficulty with this scheme are those sources of disable correlated with crossings but which need to be specific to individual triggers. A good example is the Prescaler disable, the prescale factor applied to each L1 trigger. In this case, the solution was to implement the prescale using an egalitarian algorithm making it un-correlated with crossings so long as certain prescale values are excluded (e.g. factors of 3 and 53).[1] Disables correlated with the bunch-to-bunch luminosity profile include some global disables (e.g. skip next crossing after L1 accept) and GS disables (waiting for readout) [7]. Disables not correlated with ticks include individual disables, some global disables, COOR disable, Prescaler, L2 disable, L3 disable, and Auto-disable.

Certain AOT are highly correlated with the bunch structure, for example, the live-beam-crossing term. These terms must be included in the EG definition. Other such terms include any AOT that causes a bias in the normalization such as requiring a single interaction, a tight $Z$ cut on the primary vertex, or a veto on an LM output (EG containing these AOT cannot be normalized according to the methodology described in this note). L1 triggers must include all AOT required by their EG.

Geographic sections associated with the EG containing the accepted L1 triggers are read-out upon receipt of both a L1 and L2 accept. EG allow the readout to be partitioned so that different triggers may read-out independent portions of the detector. Different runs may therefore have different readout. EG are also useful for specialty triggers defined within the "global" run such as triggers fired during the gaps between superbunches for calorimeter and AFE monitoring.

[1] This algorithm was flawed and was replaced in February 2003 with a randomizing scheme. The new prescaler is not sensitive to factors of 3 or 53.

# 6 Exposed Luminosity

The above definition of EG requires two sets of scalers. One set consists of scalers per tick per EG ($159 \times 8$) and the other consists of one scaler per L1 trigger (128). The former are those scalers associated with bunch correlations, the latter are the decorrelated scalers. The luminosity calculation proceeds as in Eq. 2;

$$\mathcal{L}_{L1}(n) = -\frac{f/159}{\sigma} \frac{\Delta decorrelated_n}{\Delta ticks} \sum_{i=1}^{159} \frac{\Delta Exposure\ Group}{\Delta ticks/159} \ln\left(1 - \frac{\Delta LM_i}{\Delta ticks/159}\right). \quad (3)$$

This formula gives the luminosity for each L1 trigger integrated over the luminosity block. Neglecting any losses (see Ref. [2] for details), the luminosity at L2 and L3 depends solely upon any prescales at those levels of the trigger. Such prescales are not taken into account when reporting the luminosity.

# References


[1] M. Begel *et al.*, *DØ Luminosity in Run 2: Delivered*, DØ Note 3970.

[2] M. Begel, *DØ Luminosity in Run 2: Recorded*, DØ Note 3972.

[3] M. Begel *et al.*, *Luminosity and Performance of DØ during the First Year of Run 2*, DØ Note 3973.

[4] M. Abolins *et al.*, *DØ Run II Level 1 Trigger Framework Technical Design Report*, 1998.

[5] D. Edmunds *et al.*, *Level 1 Trigger OR's with Pseudo-AND/OR Terms*, DØ Note 3683.

[6] S. Snyder, *COOR*, 2002.

[7] D. Edmunds *et al.*, *Online measurement of Beam Luminosity and Exposed Luminosity for Run II*, 1997.

[8] H. Schellman *et al.*, *Summary of the Luminosity Workshop — September 17-18, 1998*, DØ Note 3523.