D0 Luminosity Monitor Operations and Performance

Michelle Prewitt, Rice University for the D0 Luminosity Group
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Overview

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D-Zero

Forward Mini-Drift Tubes

Muon Toroid

Muon Scintillation Counters

Tracking System: Silicon, Fiber Tracker, Solenoid, Central & Forward Preshowers

Fiber Tracker/Preshower VLPC Readout System

p-pbar
CoM=1.96 TeV
Luminosity Monitor Basics

- 48 scintillating wedge with PMT channels separated into 2 arrays, North and South
- Covers a pseudo-rapidity of $2.7 < |\eta| < 4.4$
Luminosity Highlights

- Peak D0 Luminosity: $4.21 \times 10^{30}$ cm$^{-2}$ s$^{-1}$
- Delivered (Recorded) Luminosity: $11.18 \ (10.01)$ fb$^{-1}$
- Stability: $\pm 0.5\%$
Luminosity Measurement

- Luminosity at D0 is measured by a technique called “counting empties”.
- Particles that hit the detector come from inelastic collisions in the beam interaction.
- A hit in the luminosity monitors requires an in-time coincidence in both sides.
- By counting the number of hits and number of crossings, the number of empties can be determined.
- Then the luminosity measurement is made using the number of empties and Poisson statistics.
- Part of the luminosity measurement is luminosity constant.
- The luminosity constant, $\sigma_{\text{eff}}$, is the effective cross section seen by the luminosity monitor.

$$P(0) = e^{\sigma_{\text{eff}} L/\nu} \ast \left(2e^{-\sigma_{\text{ss}} / 2\nu} L - e^{-\sigma_{\text{ss}} L / \nu}\right)$$
Luminosity Measurement

- The luminosity measurement is made separately for each of the 36 bunch.
- The bunches are distributed into 3 groups of 12 bunches, a train, separated by abort gaps.
Luminosity Measurement

- Luminosity system also measures and monitors the beam halo.
- Halo comes from particles that travel with the beam but are outside the beam pipe.
- Normally caused by an escaped proton or anti-proton that causes a shower upstream of the luminosity monitor.
The period after the March 2006 shutdown is referred to as Run IIB at D0.

During the shutdown, an additional silicon layer was added to the D0 detector.

While the effect to the luminosity constant was expected to be small, it was important to re-evaluate the luminosity constant for this period.

This work included taking new data sets, updating the Monte Carlo (MC), and improving the analysis technique among other tasks.

The result is a noticeable improvement on the luminosity measurement systematic uncertainty.

Results will be publically available soon!
MC Geometry Upgrades

- The addition of an inner layer to the Silicon Microstrip Tracker in 2006 meant changes to the beam pipe and support structure as well as the silicon system.
- The luminosity system pre-amplifier boards were also upgraded in 2006, so the luminosity monitor geometry needed to be updated.
- The LM is particularly sensitive to material in the forward region, so it was important to improve the material description in the high-eta region.
- The effect of the missing material is small at low pseudo-rapidity, but not for particles traveling to the luminosity monitor.
MC Geometry Upgrades

- Half slice of inner D0 Detector
Both arrays of the luminosity monitor have 2 enclosures: East and West.
This allows the LM to be removed for maintenance periods.
This picture is of the North array taken during the summer of 2009. During normal operations, this view is not possible.
Luminosity Monitor

- Scintillator
  - Saint-Gobain BC 408

- PMT
  - Hamamatsu R7494
  - 1” fine-mesh tube
  - Operates in ~ 1.25T magnetic field

- Pre-Amp boards\(^1\)


Open LM enclosure.
NIM System – Halo measurement

VME System – Luminosity Measurement

The VME system uses ADC and TDC to determine the charge and timing separately for all channels.
Operations

- Calibrations
  - Timing
  - ADC Pedestals
- Monitoring
  - ADC/lumi Plots
  - HV Scan
  - Threshold Scan
- Maintenance
  - HV Updates
  - Shutdowns
- Challenges

LM enclosure with the scintillator and PMTs removed during a maintenance period.
The timing window for a hit to the D0 luminosity system is ±6.4 ns relative to nominal.

The window is set to separate halo interactions and hits from inelastic beam collisions.

Plot of the timing for a single channel during the halo removal process before the store. During this time, the luminosity voltage is set to 70% of the appropriate value. *This data is not used for physics analysis.
Timing Calibration

- To ensure that good hits do not drift outside the timing window, the timing calibration is adjusted to keep the mean time for each channel within ±1 ns.

- Timing drifts occur because the signal for collisions sent from the Accelerator Division on cable which expands and contracts with the temperature variation of the seasons.

Before Calibration
Mean_Time = -0.87

After Calibration
Mean_Time = -0.10

$L \sim 120E30$
Pedestal Calibrations

- Pedestals shift slowly due to temperature variations.
- Try to keep within a ±4 pC range
  - 4 pC = 33 µV @ pre-amplifier input
HV Updates

- Use ADC versus luminosity plot and HV and Threshold Scans to determine when to raise the HV setting on the PMTs.
- The HV is adjusted to compensate for radiation damage to the scintillator.
- Gains are set so that the anode current is 18 µA at a luminosity of 300E30.
- In practice, the HV is raised approximately every 1 fb⁻¹ of delivered luminosity.
- This adjustment only works as long as the scintillator is not badly damaged.
- Then it is time to change scintillator.
Average charge for a single channel normalized by the instantaneous luminosity versus integrated delivered luminosity (fb⁻¹)
During long accelerator downtimes (1+ month), the opportunity to do maintenance on the luminosity system is taken.

The main task of the shutdown is a full scintillator replacement.


The 2010 shutdown was exciting because the timeline for the work was cut in half, compared to previous shutdowns.

Also during the 2010 shutdown, 14 of the 48 PMTs were replaced.
Shutdown

- Working around the beam pipe.

Photo courtesy of Mike Cooke
This scintillator accumulated $3.6 \text{ fb}^{-1}$ of delivered luminosity over a 2 year period.

This is the most luminosity delivered to a batch of scintillator before replacement.

For more information see Jesus Orduna’s talk “Radiation Damage Studies and Operations of the D0 Luminosity Monitor”. 

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One issue the luminosity group has had to deal with recently is a double peak structure in the timing distribution of some channels at high luminosity.

This behavior is due to electronics saturation along the signal chain.

While this behavior is undesired, it has not effected the luminosity measurement.

The issue is still being monitored.

As the HV continues to need to be increased and the Accelerator Division provides higher initial luminosity stores, it is important to make sure this feature does not become a problem.
Challenges – Timing

1st Problem Channel
L ~ 280
The D0 luminosity system is very robust.

The LM is maintained to keep the luminosity measurement within a ±0.5% stability range.

Expect to see an update on the Run IIB luminosity constant documentation with improved luminosity uncertainty soon.

Operations of the luminosity monitor is vital to continuing to collect good physics data at D0.

Thanks to all who contribute to this effort!
Backup
MC Geometry Upgrades

- Zoomed in MC drawing of the outer SMT and beam pipe region.
Scintillator

2010

New

2.2 fb

-1

2009

New

3.6 fb

-1