# D0 Luminosity Monitor Operations and Performance

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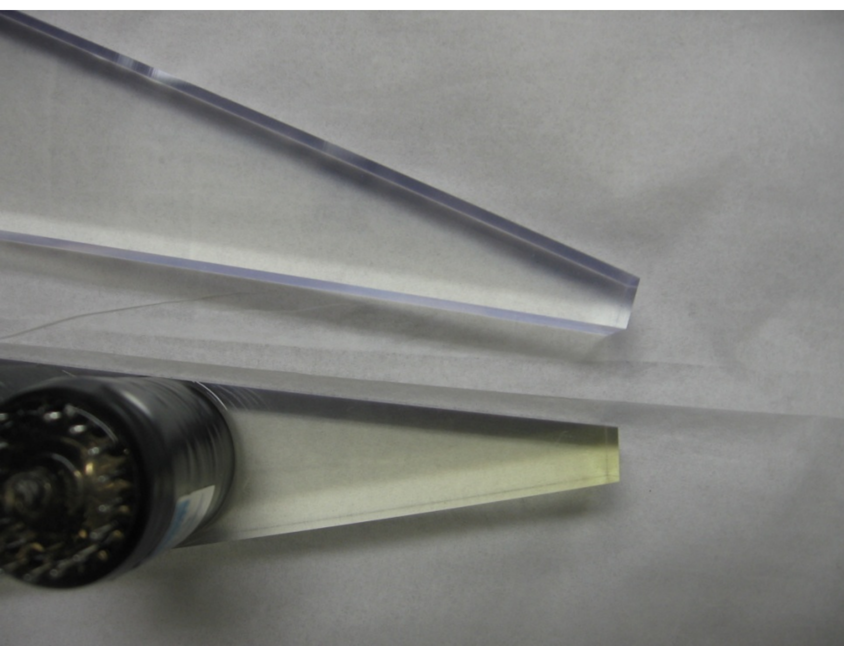
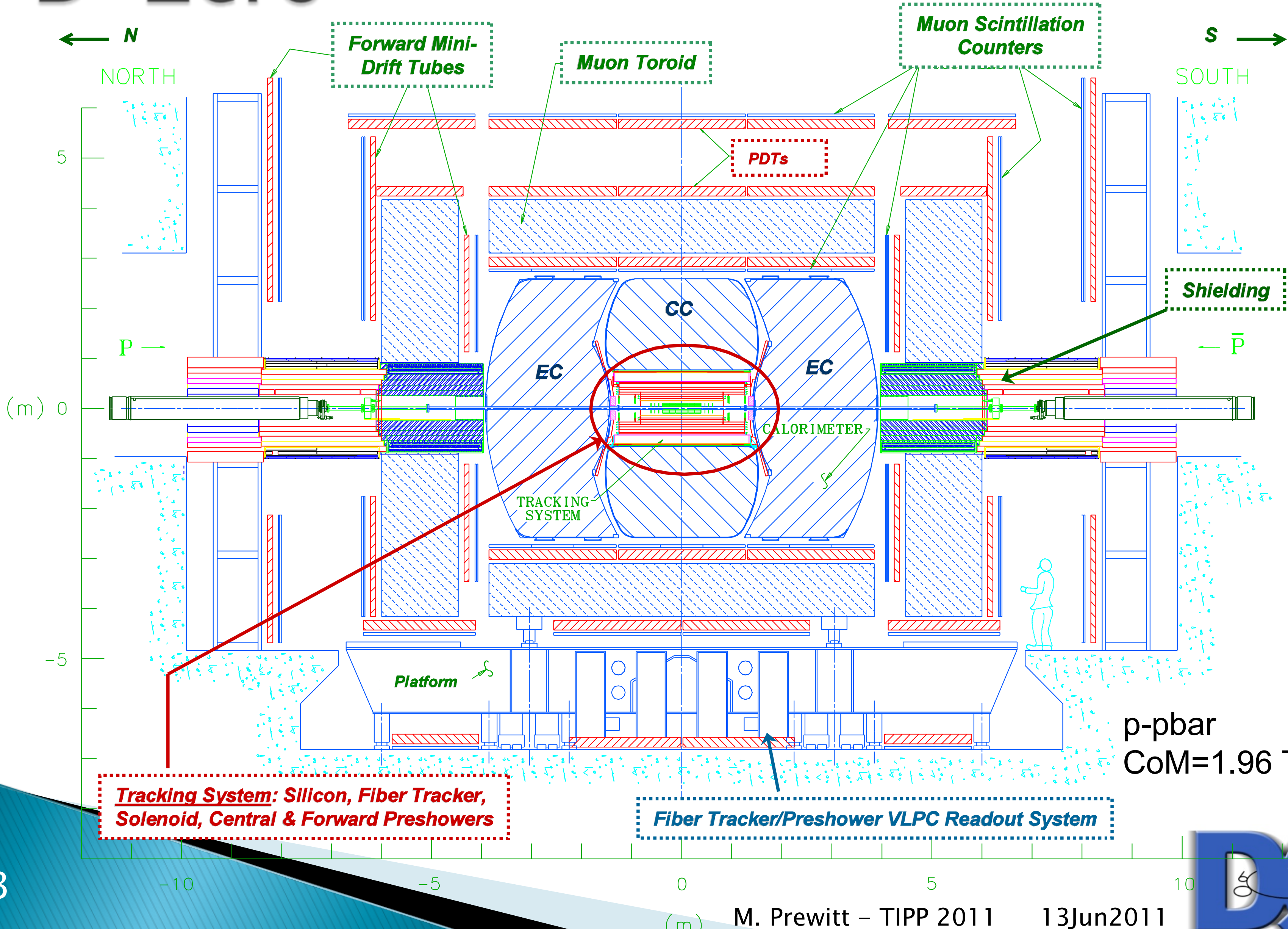


# Overview

- Introduction
- Luminosity Measurement
  - Luminosity Constant
- Luminosity Monitor
- Operations
  - Calibrations
  - Gains
  - Shutdowns
  - Challenges
- Conclusions

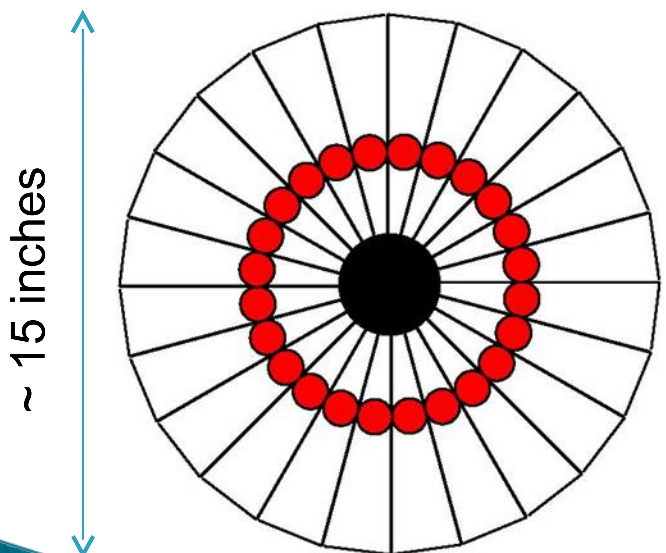
# D-Zero

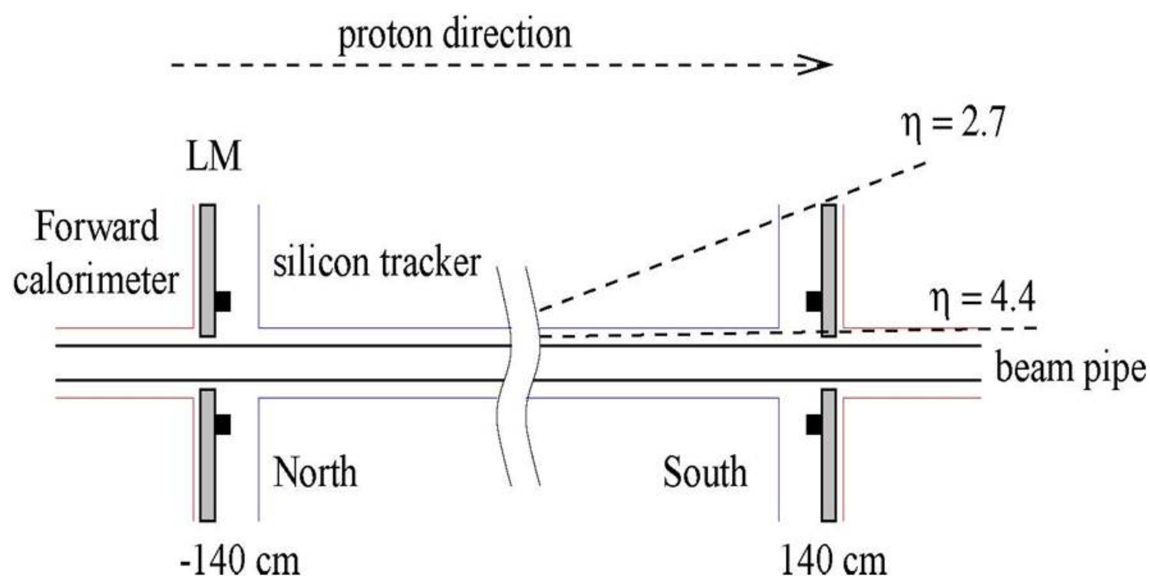



p-pbar
CoM=1.96 TeV

# Luminosity Monitor Basics

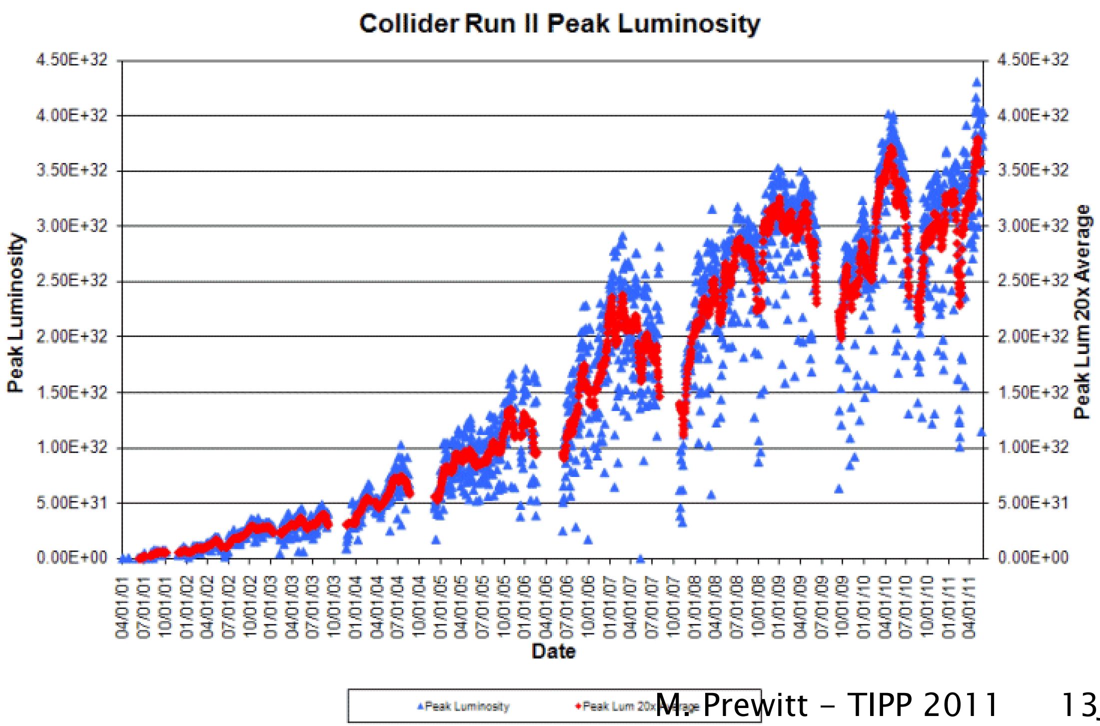
- 48 scintillating wedge with PMT channels separated into 2 arrays, North and South
- Covers a pseudo-rapidity of $2.7 < |\eta| < 4.4$



# Luminosity Highlights

- Peak D0 Luminosity: 421E30 $cm^{-2}$ $s^{-1}$
- Delivered (Recorded) Luminosity: 11.18 (10.01) $fb^{-1}$
- Stability: $\pm$0.5%



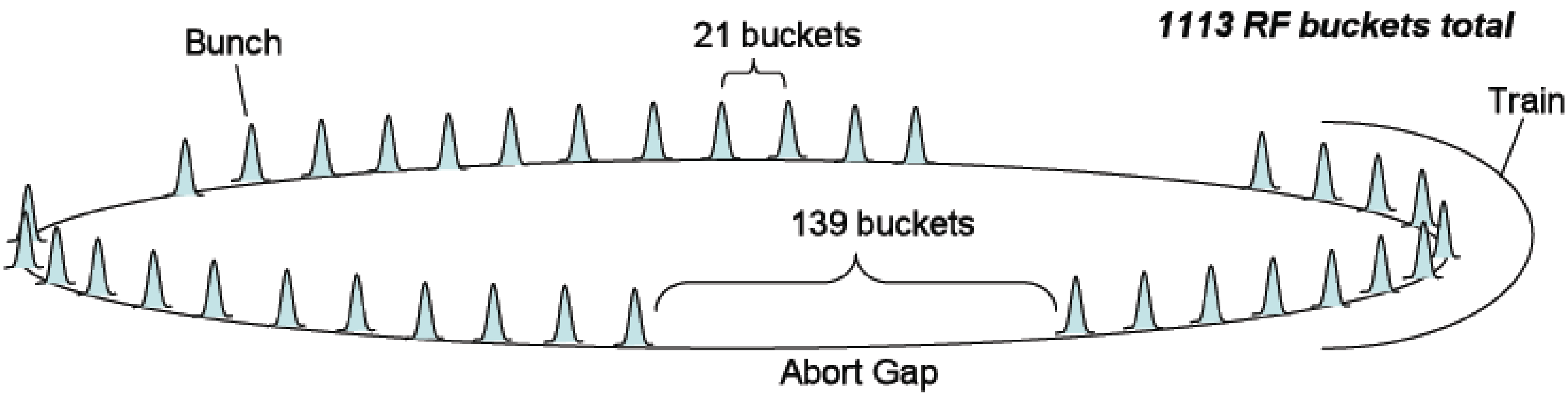
# Luminosity Measurement

- 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, $\sigma_{eff}$, is the effective cross section seen by the luminosity monitor.

$$P(0) = e^{\sigma_{eff} L/\nu} * \left( 2e^{(-\sigma_{SS}/2\nu)L} - e^{-\sigma_{SS} L/\nu} \right)$$

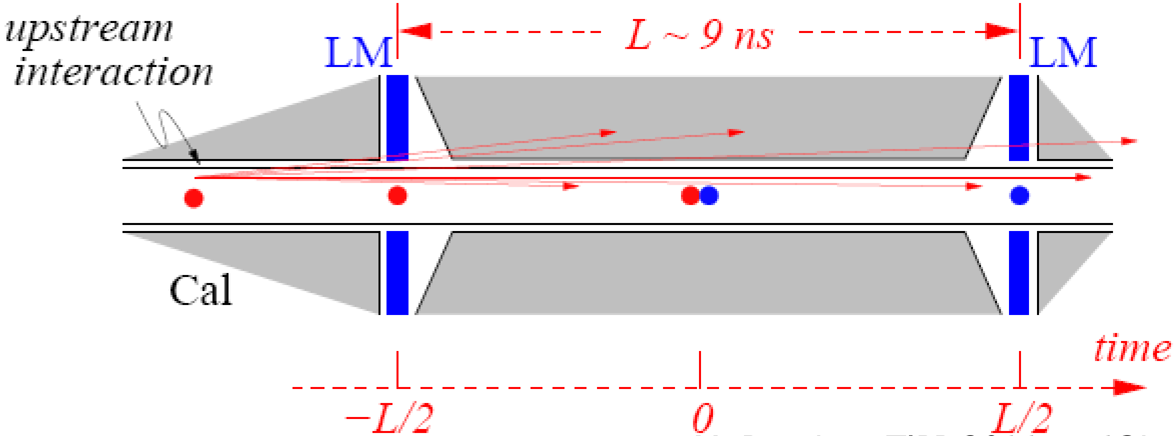
# Luminosity Measurement

- 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.



# Run IIB Luminosity Constant

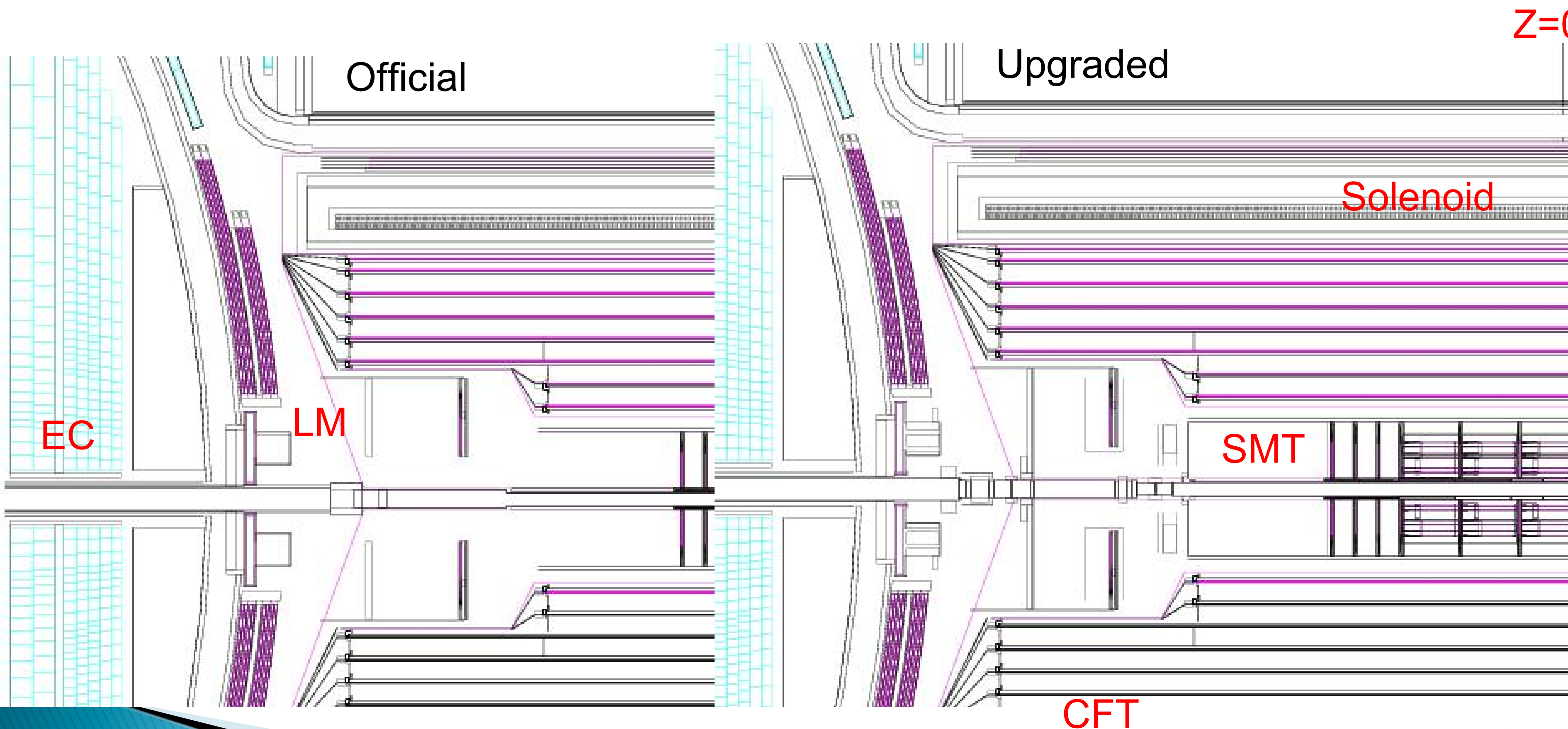
- The period after the March 2006 shutdown is referred to as Run IIB at D0.
- During the shutdown, an additional silicon layer was added to the D0 detector.
- While the effect to the luminosity constant was expected to be small, it was important to re-evaluate the luminosity constant for this period.
- 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.

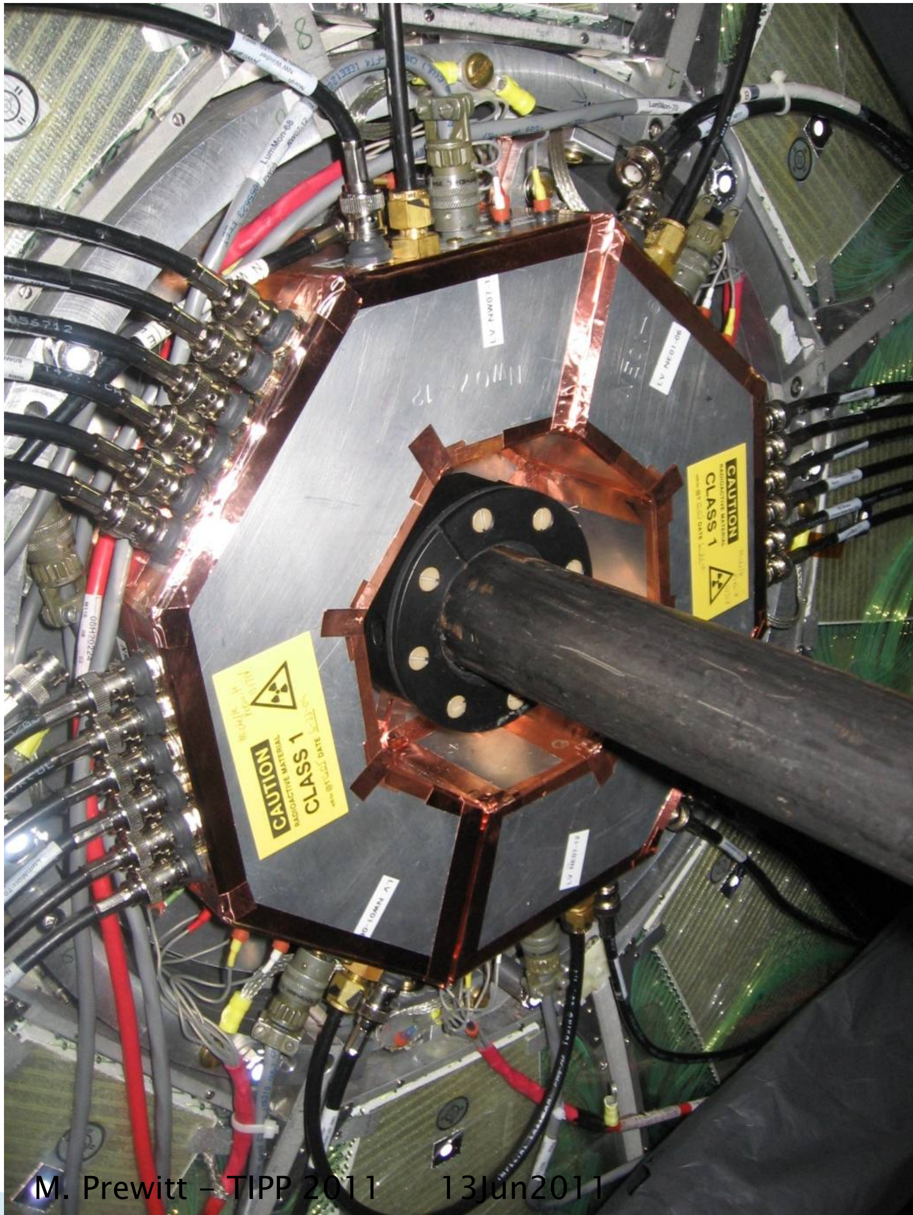
# MC Geometry Upgrades

- Half slice of inner D0 Detector



# Luminosity Monitor

- 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.



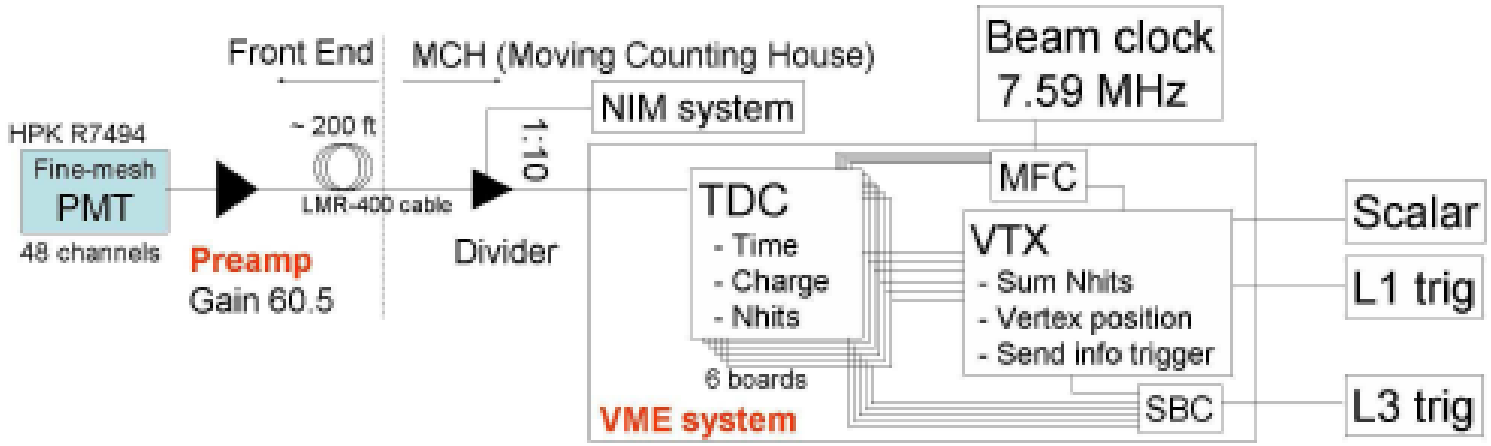
# Luminosity Monitor

- 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.

[1]J. Anderson et al., Nuclear Science Symposium Conference Record, 2006. IEEE 1 (2006) 503-506.

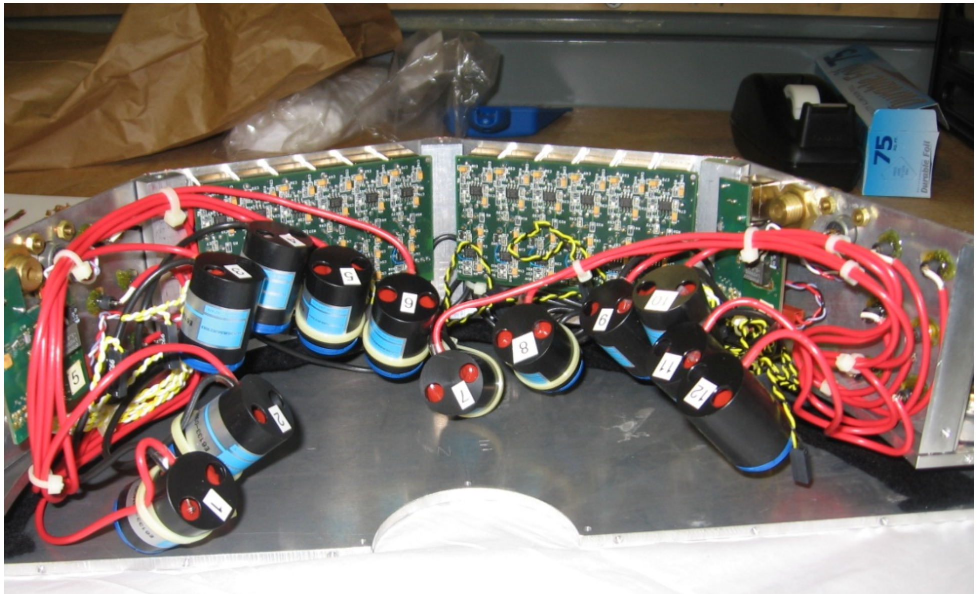
# Luminosity Electronics Readout




- 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

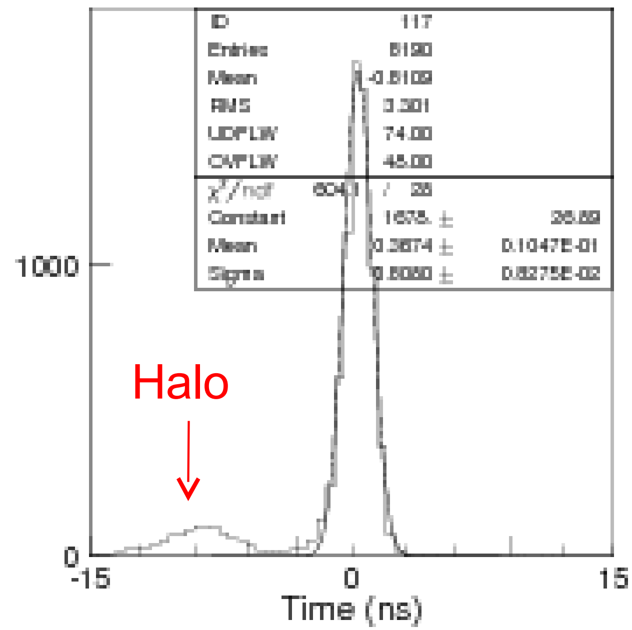
- Calibrations
  - Timing
  - ADC Pedestals
- Monitoring
  - ADC/lumi Plots
  - HV Scan
  - Threshold Scan
- Maintenance
  - HV Updates
  - Shutdowns
- Challenges



LM enclosure with the scintillator and PMTs removed during a maintenance period.

# Timing Calibrations

- 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.

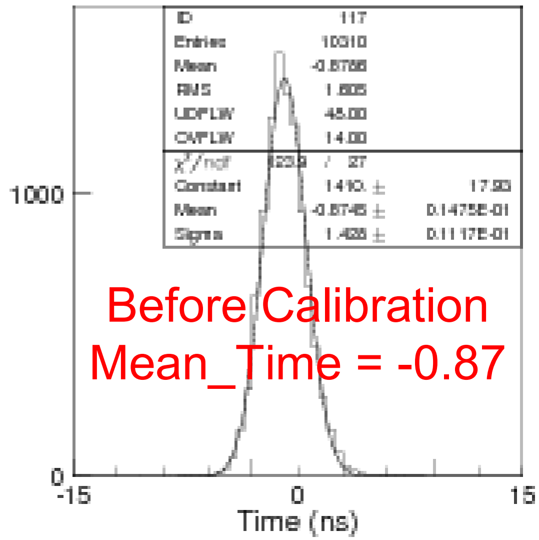


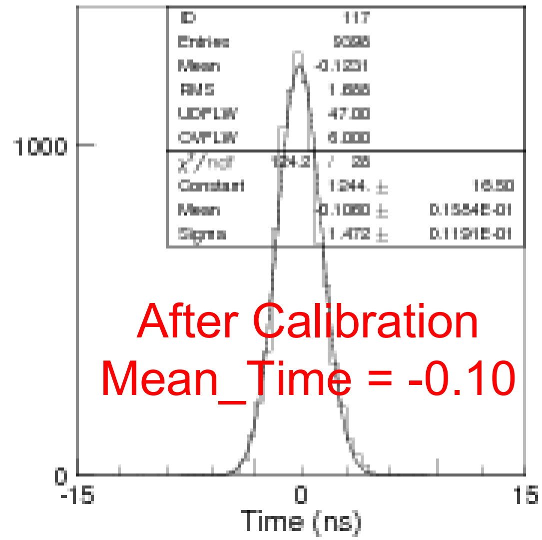

Plot of the timing for a single channel during the halo removal process before the store. During this time, the luminosity voltage is set to 70% of the appropriate value. *This data is not used for physics analysis.

# 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.

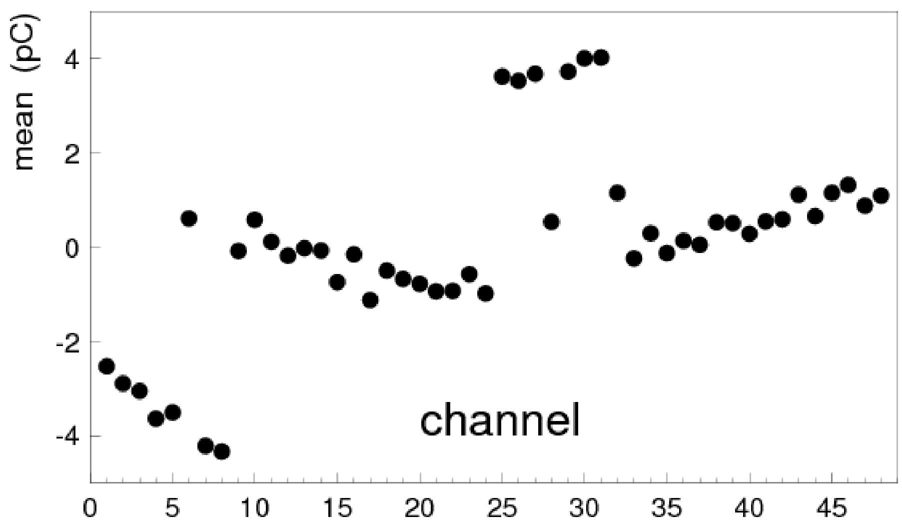
L ~ 120E30



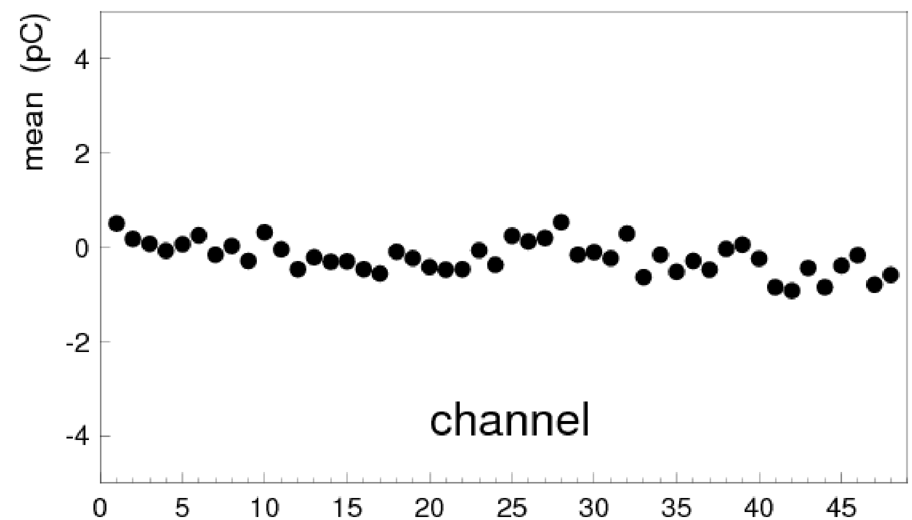



# Pedestal Calibrations

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




Needs Calibration

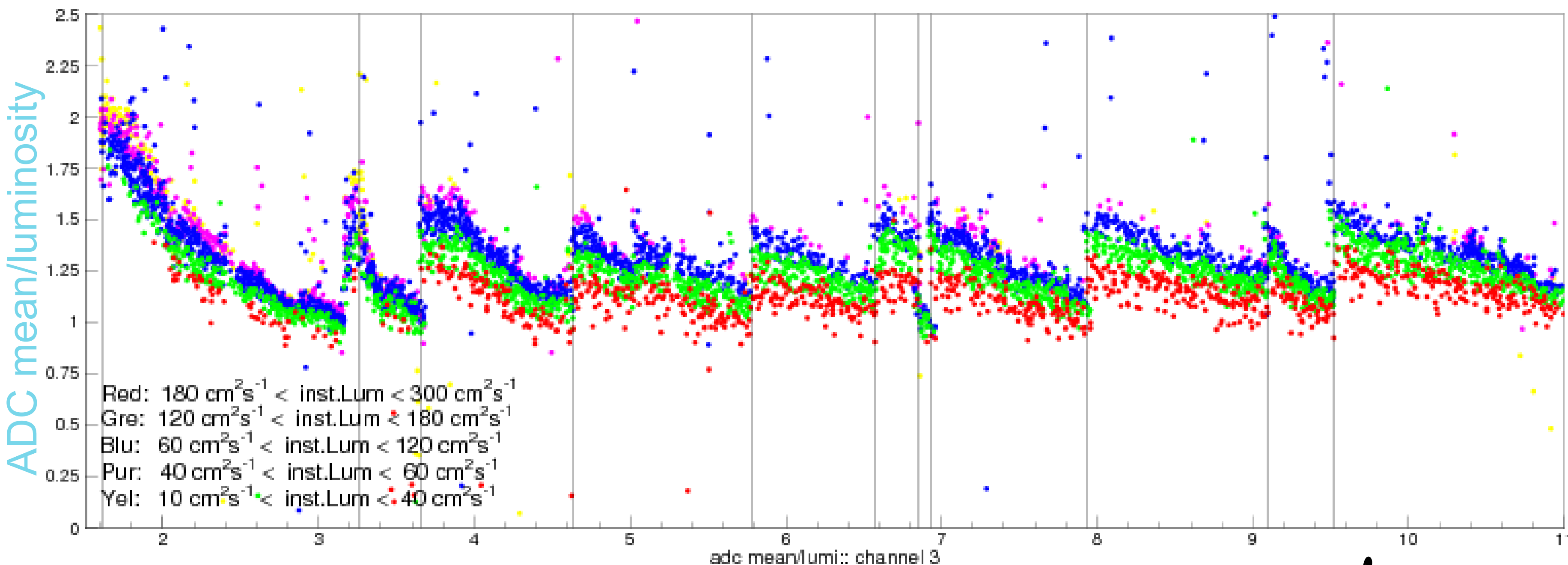



Calibrated

# 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.

# ADC vs Luminosity Plot




$$\int L_{Del} dt$$

- Average charge for a single channel normalized by the instantaneous luminosity versus integrated delivered luminosity ($fb^{-1}$)

# Shutdowns

- 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.
- Scintillator was replaced in Summer 2006, 2007, 2009, and 2010.
- 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

# 2009 Scintillator Replacement

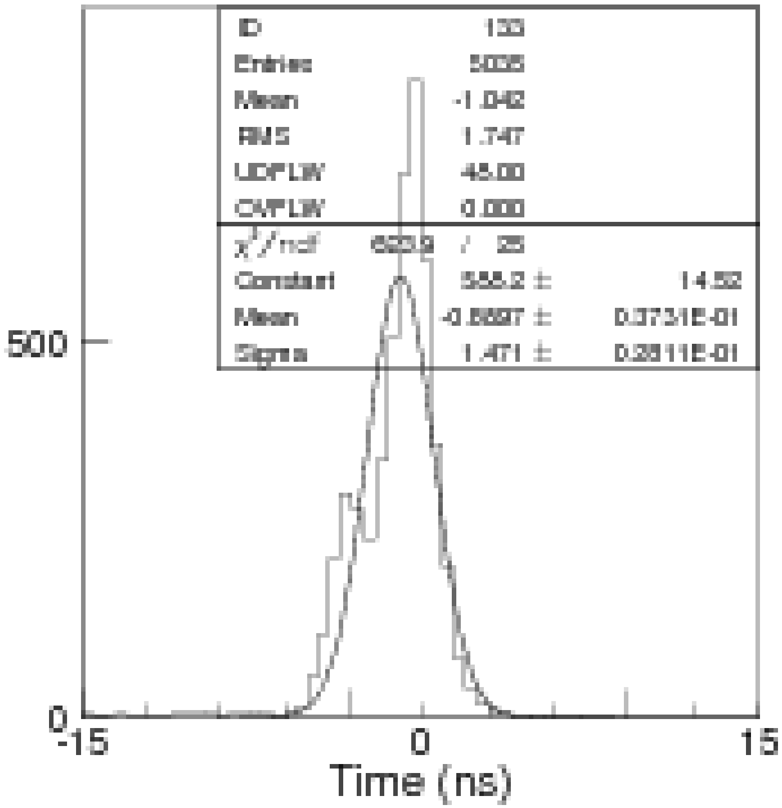
- This scintillator accumulated 3.6 $fb^{-1}$ of delivered luminosity over a 2 year period.
- This is the most luminosity delivered to a batch of scintillator before replacement.


For more information see Jesus Orduna's talk "Radiation Damage Studies and Operations of the D0 Luminosity Monitor".

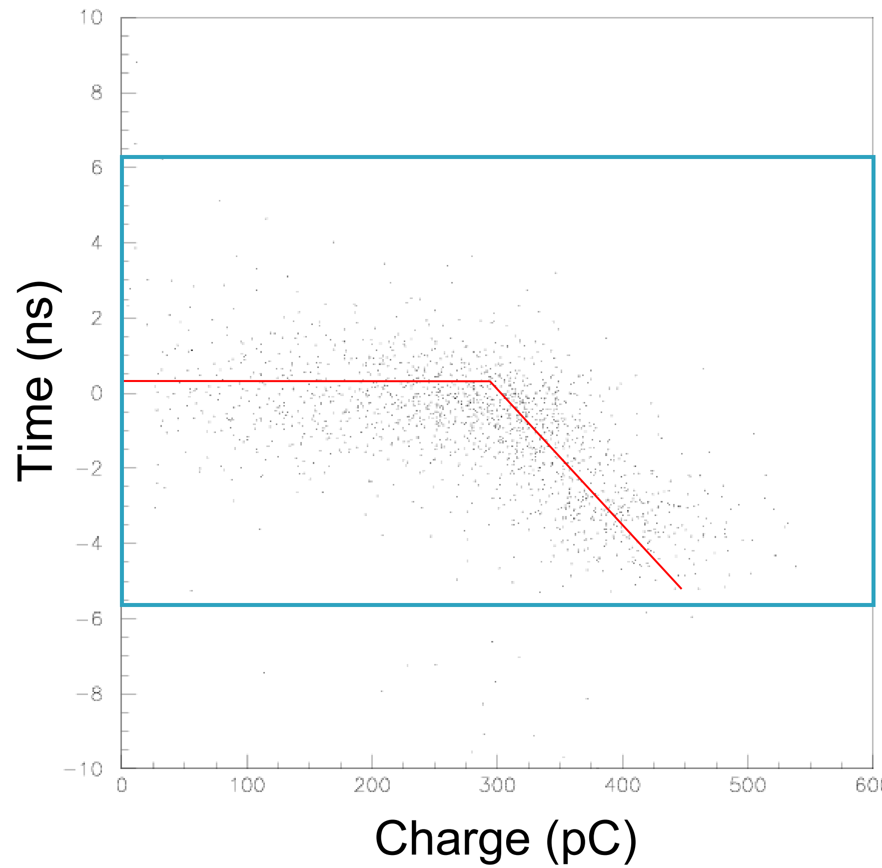
# Challenges – Timing

- 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



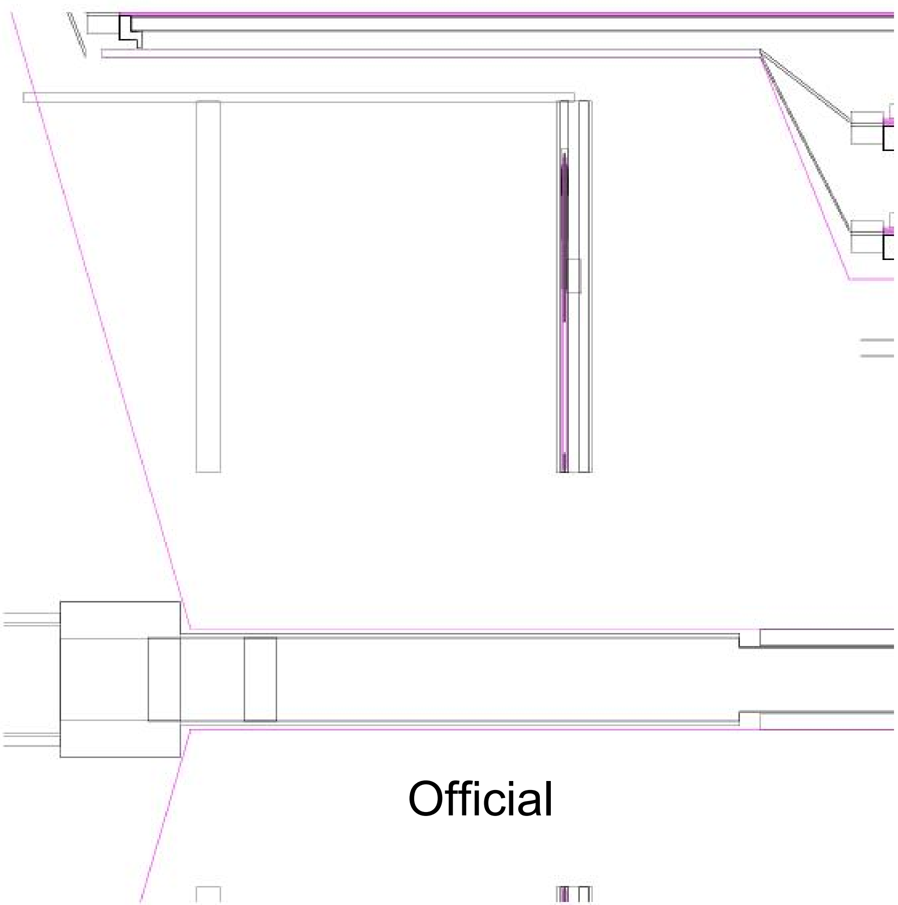
# Conclusions

- The D0 luminosity system is very robust.
- The LM is maintained to keep the luminosity measurement within a $\pm 0.5\%$ 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