Radiation Damage Studies and Operation of the DØ Luminosity Monitor

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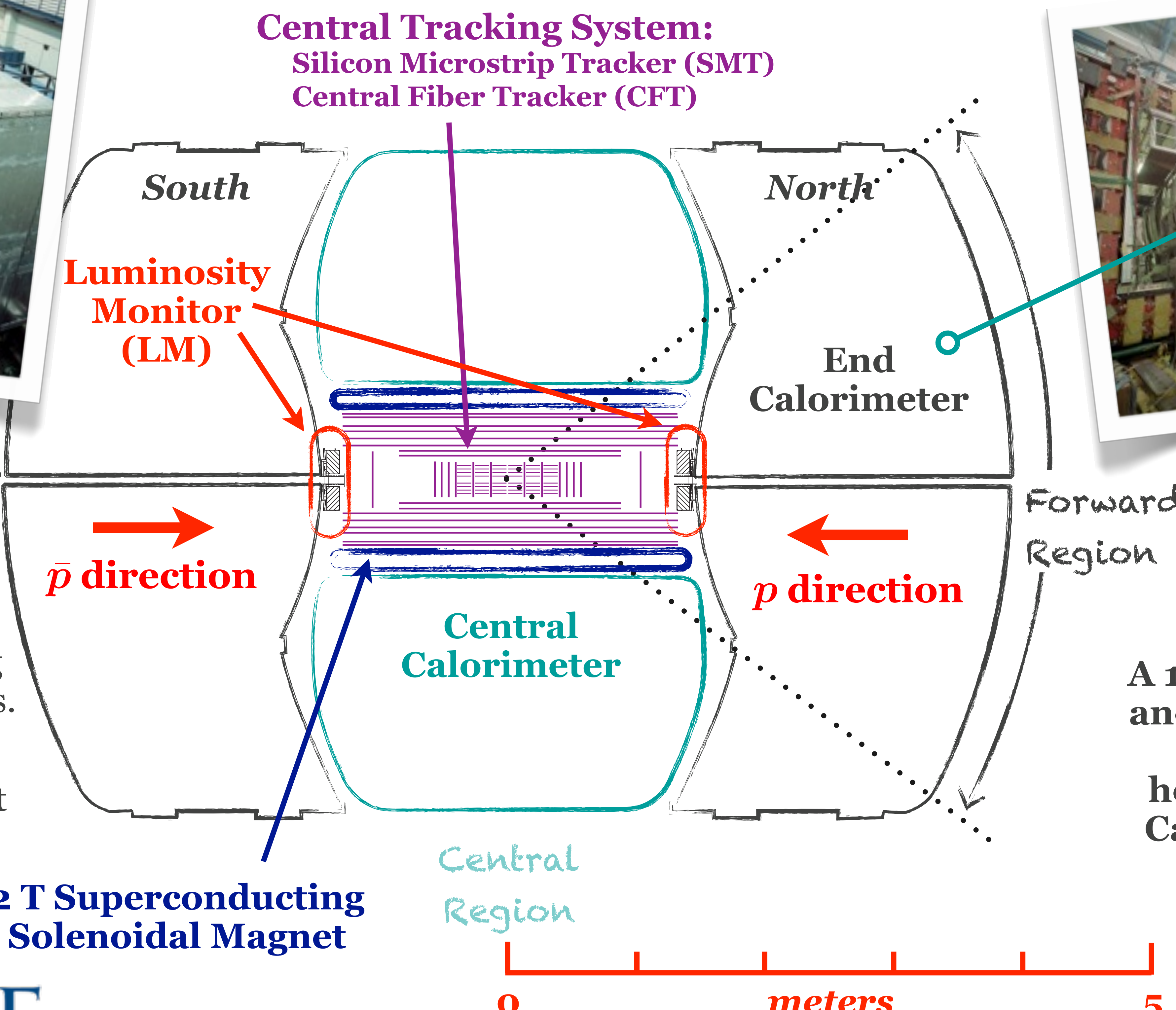
For the DØ Luminosity Group

Outline

- Basics of the DØ luminosity monitor.
- Damage to the scintillator.
- How to compensate for damage.
- Summary.

DØ Detector

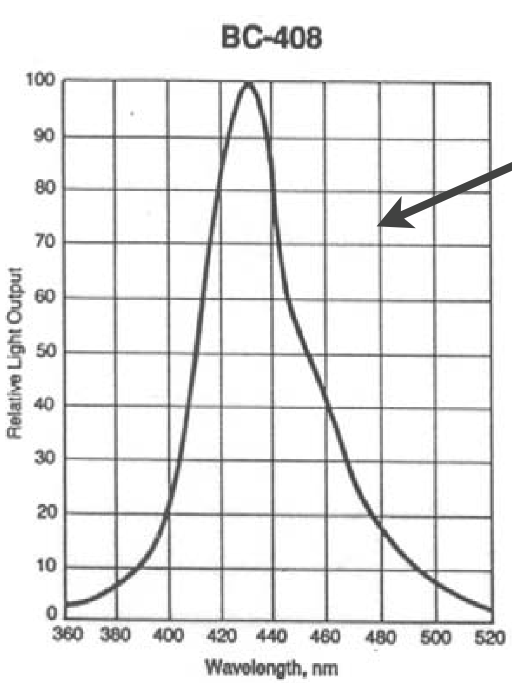


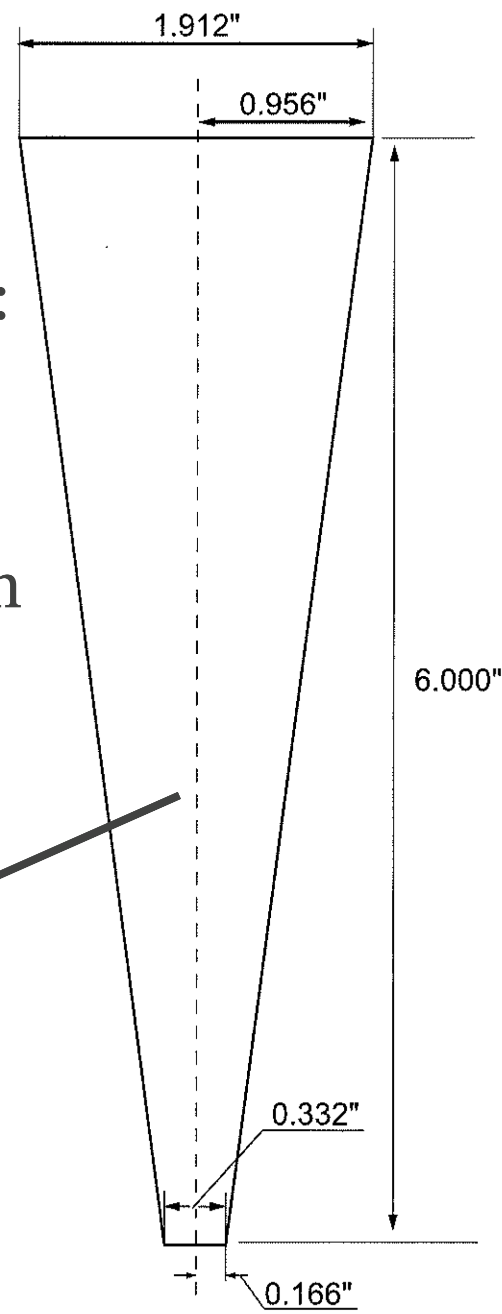
- The LM Measures Tevatron instantaneous luminosity at the DØ interaction point by detecting inelastic collisions.
- Also provides information about beam halos, both proton and antiproton.

A 1.8 T Toroid and the Muon System housing the Calorimeter

Individual Channel

- Saint–Gobain BC–408: Polyvinyl toluene + Anthracene.
- Peak output wavelength of BC–408 is 425 nm.





Scintillator dimensions in inches.

- **HAMAMATSU** R7494 (custom made*): 1” diameter fine mesh PMT with quartz windows (to improve radiation hardness) run under negative voltage.
- Operating in an ~ 1.25 T magnetic field.
- Sensitivity between 400 to 500 nm.

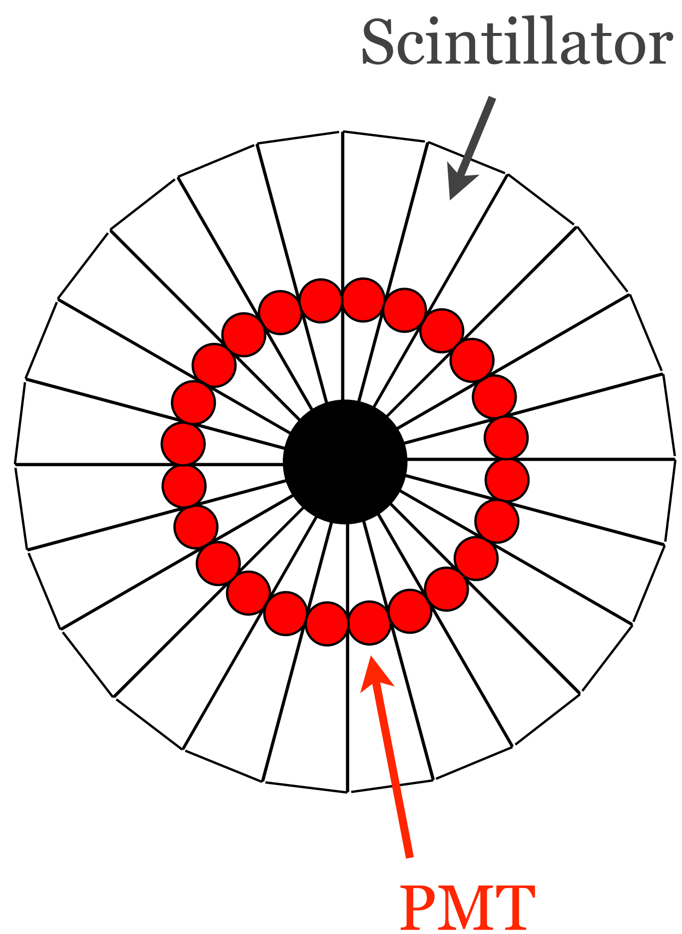
Luminosity Monitor

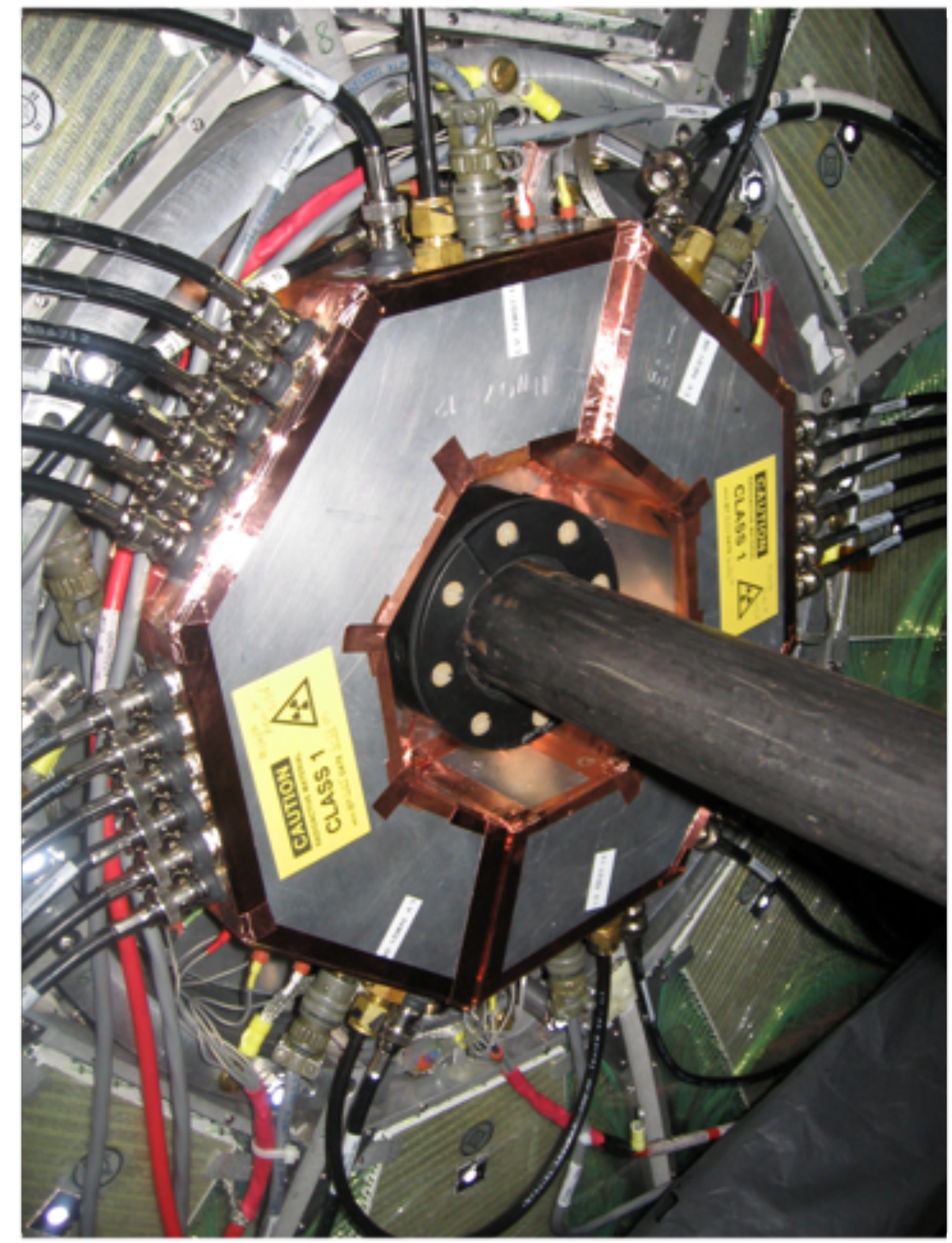
An individual channel consist of a PMT glued to a scintillator wedge.

Twelve channels form a single enclosure.

Two enclosures are mounted around the beam pipe to provide an array of 24 channels on either side.

Two arrays (one north + one south) make the **Luminosity Monitor or LM** (total: 48 channels).

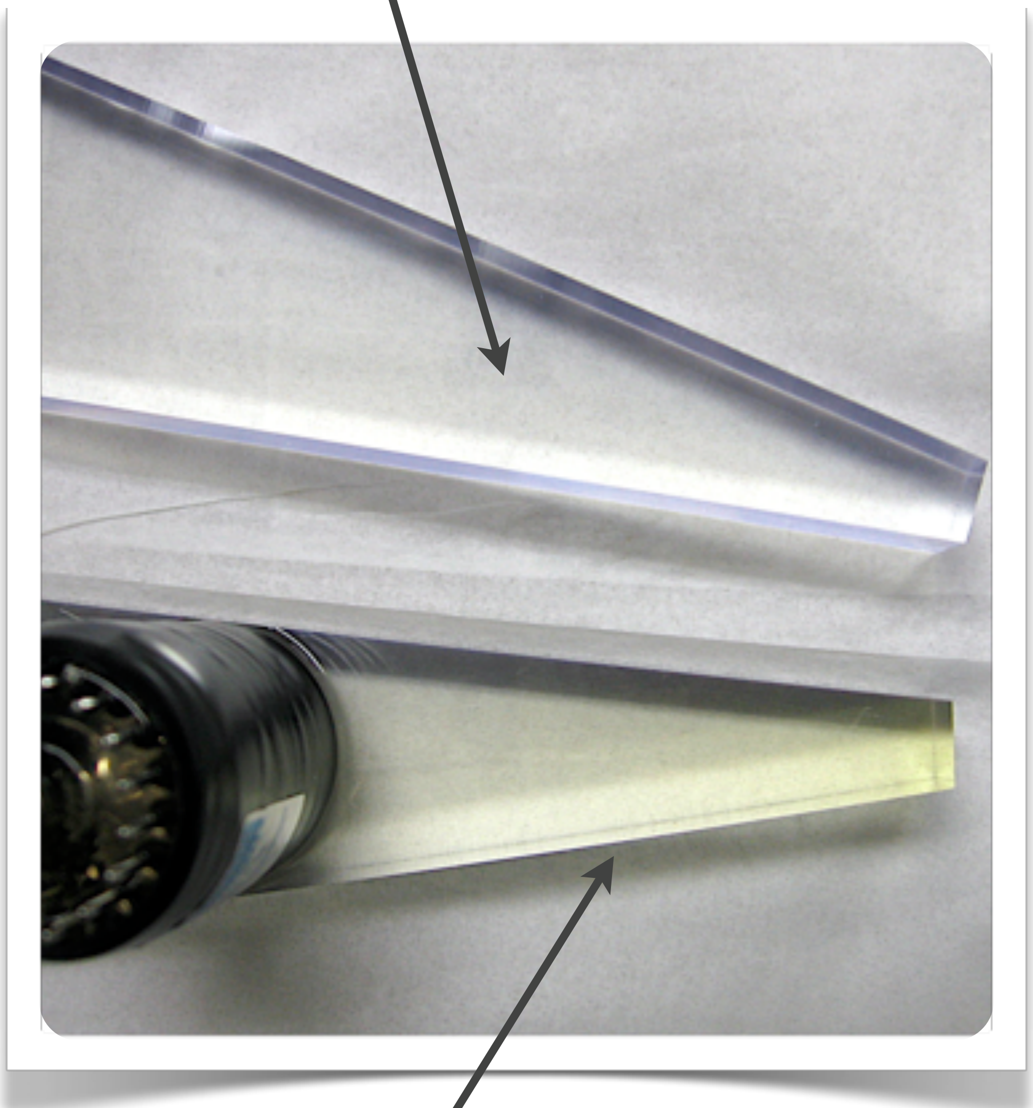




Operational Environment

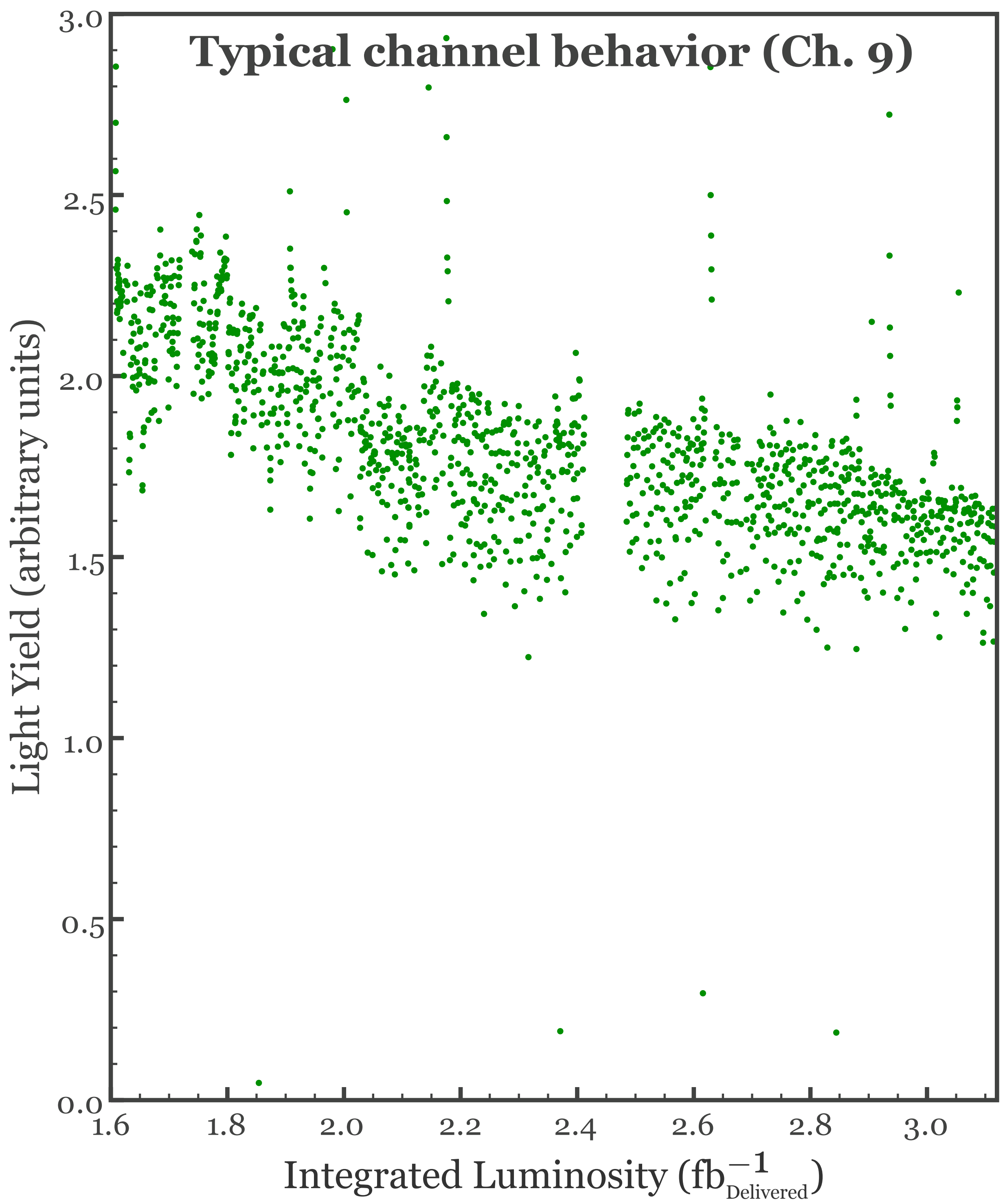
- Tevatron produces $p\bar{p}$ collisions at 1.96 TeV in the center of mass.
- Aside from Tevatron shutdowns or long downtimes, the LM is bombarded practically around the clock by ionizing radiation from beam interactions.
- Just few opportunities to perform maintenance in LM enclosures.
- The damage is not uniform.
- A large fraction of this damage is permanent due to changes in the scintillator at a molecular level.

Unused



Replaced ($3.6\ fb^{-1}$)

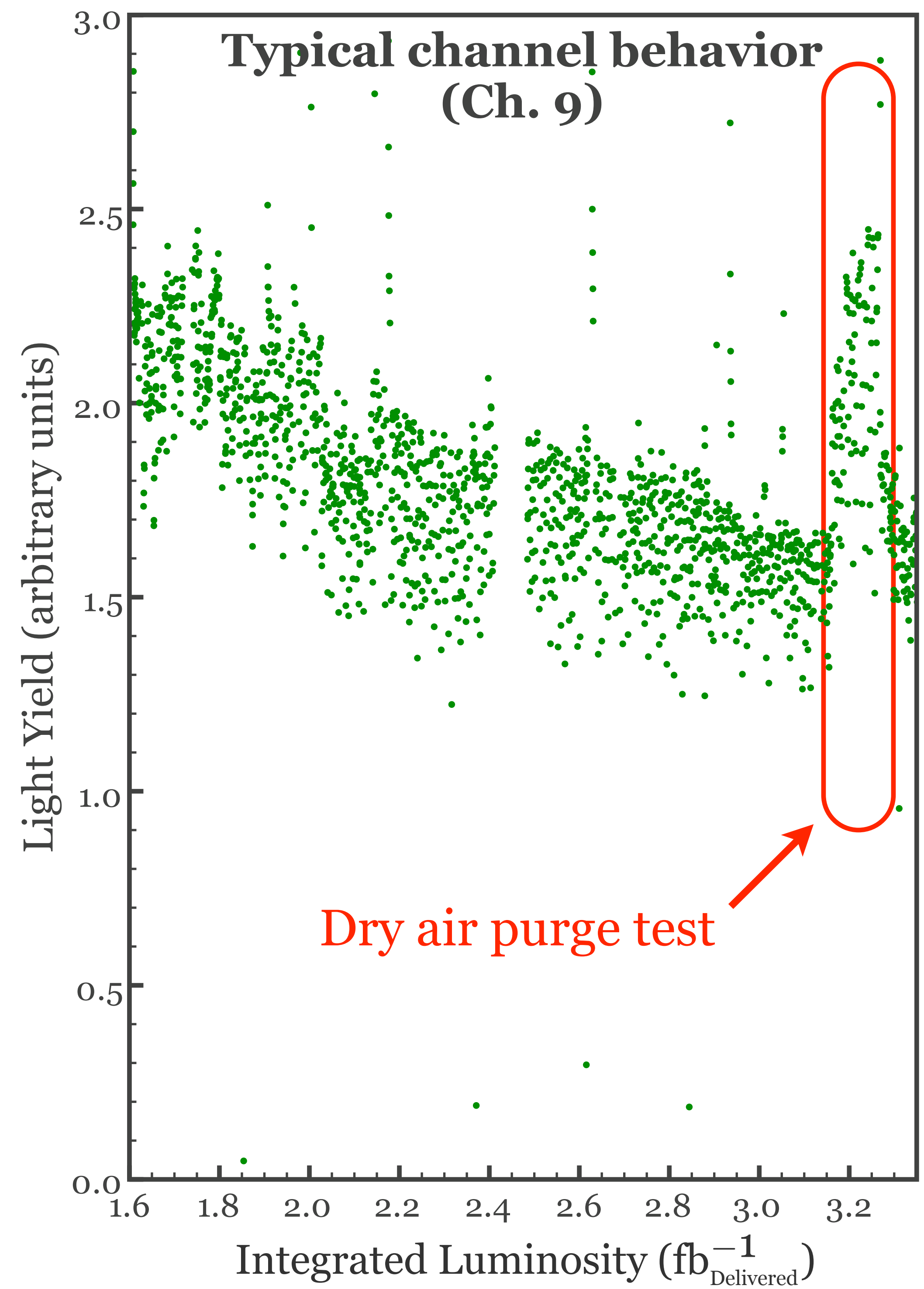
Scintillator Damage



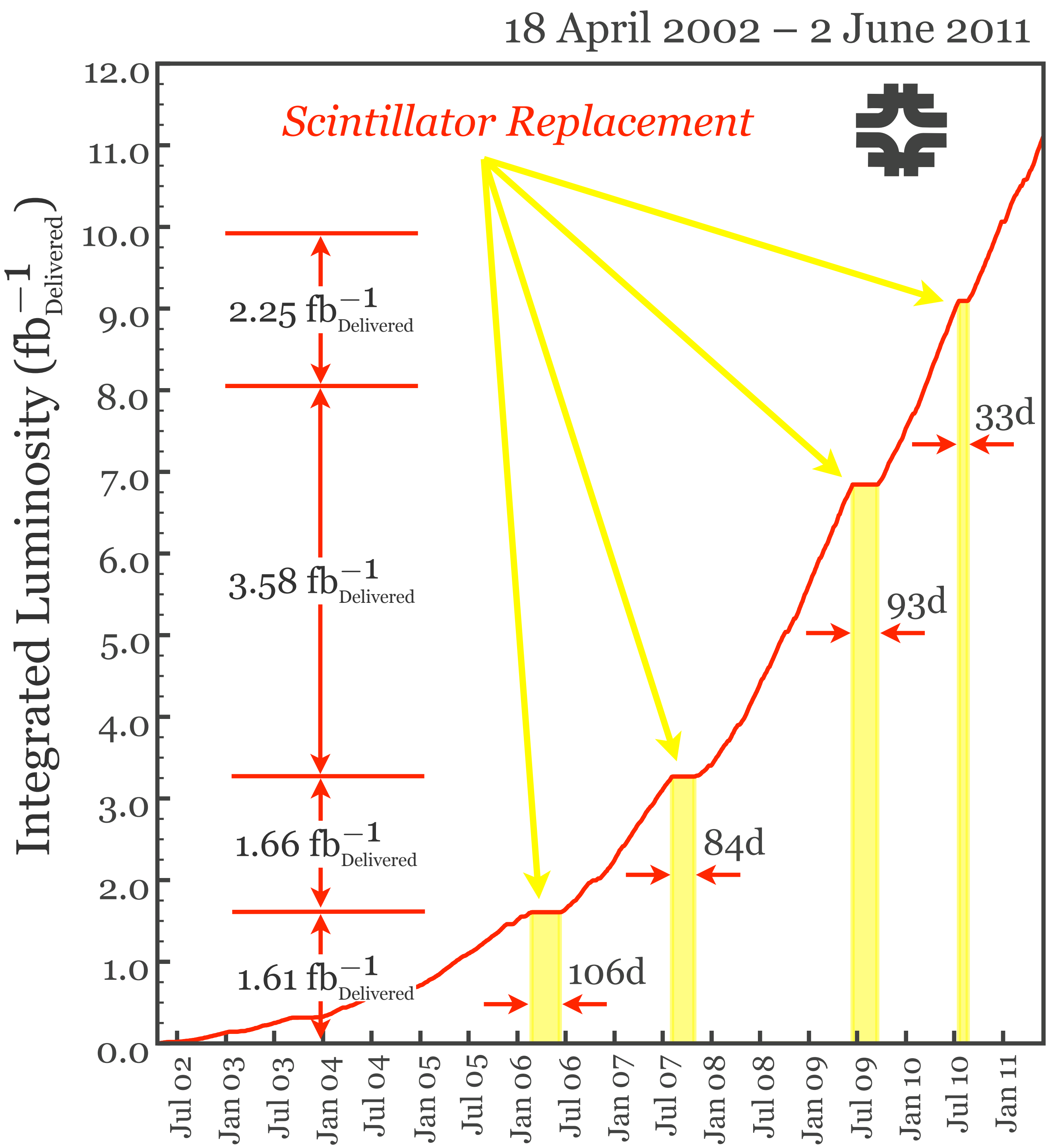
- The light yield decreases with time as the scintillator accumulates radiation damage.
- There are ways to compensate to some degree in order to provide a stable luminosity measurement:
  - Annealing,
  - HV adjustment,
  - Scintillator/PMT replacement.

Annealing

- The LM is continuously purged with gas to retard helium infiltration.
- Until the summer of 2007, the gas used was nitrogen.
- Annealing occurs when the scintillator is not exposed to radiation –preparation for beam collisions, shutdowns, etc.– partially recovering its properties.
- Nitrogen was replaced with dry air to allow the scintillator to anneal.
- Good improvement in light yield was seen (right).



Scintillator Replacement

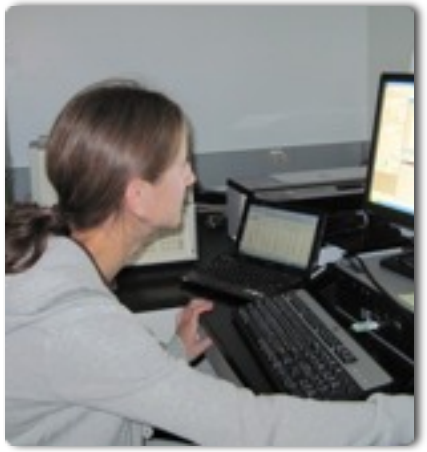


- Tevatron shutdowns. Time to do maintenance and upgrade both the accelerator and the detectors.
- For the LM generally means work in a confined space and have the scintillator replaced as safely and efficiently as possible.
- The scintillator was completely replaced in shutdowns: 2006, 2007, 2009 and 2010.
- 2010: quickest replacement (2 weeks out and in), also replacement of 14 PMT.

Spectrophotometry

Michael Eastwood
Undergrad
Rice University

Measurements 2009



Rebecca Kusko
Undergrad
Rice University

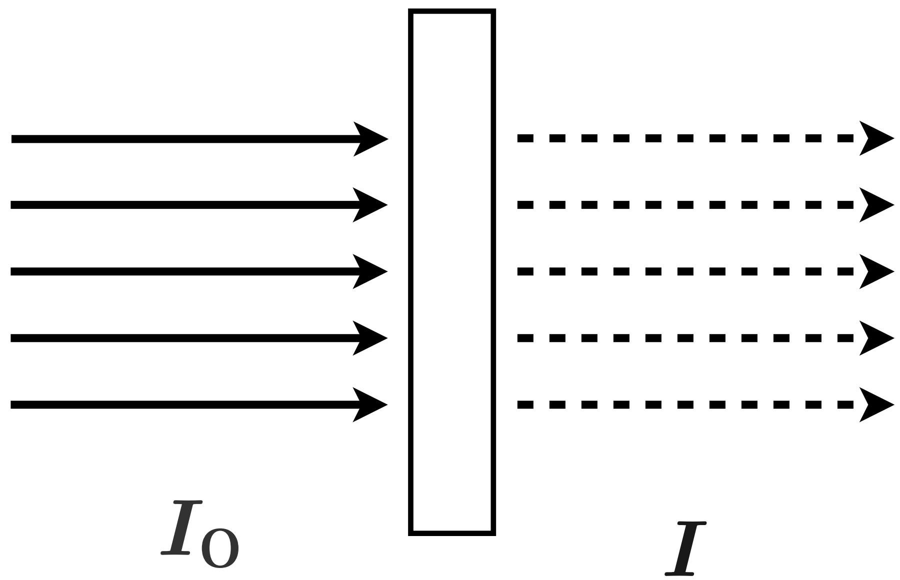
Measurements 2010

- Spectrophotometry of the scintillator motivated by a longevity study of the Luminosity System for an extended period of run without shutdowns.
- Deuterium light source integrated over a 2 s exposure.
- Wavelengths on the range from ~200 nm to 800 nm (2 nm steps in 2009 and 1 nm step in 2010).
- Great opportunity for students to get involved in detector activities.

RICE

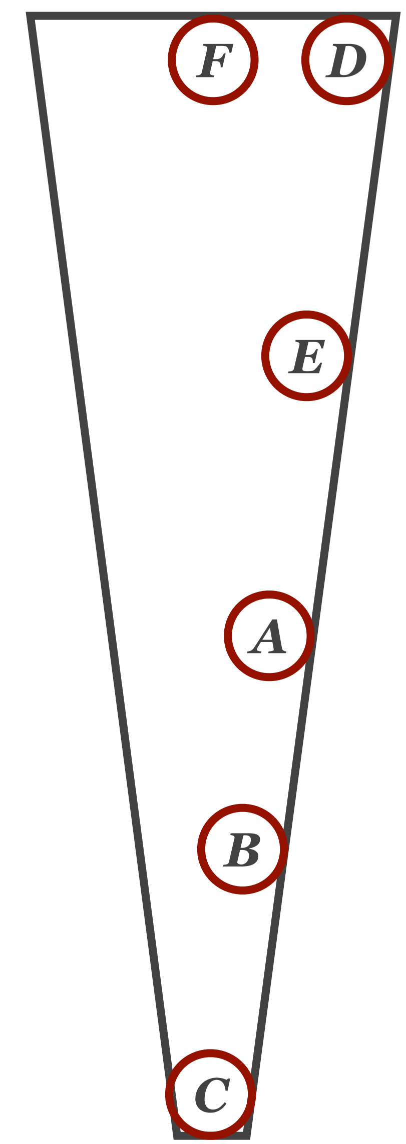
Thanks to Anna Pla–dalmau from Lab 6!

Spectrophotometry



$$\mathcal{T} = \frac{I_0}{I}$$

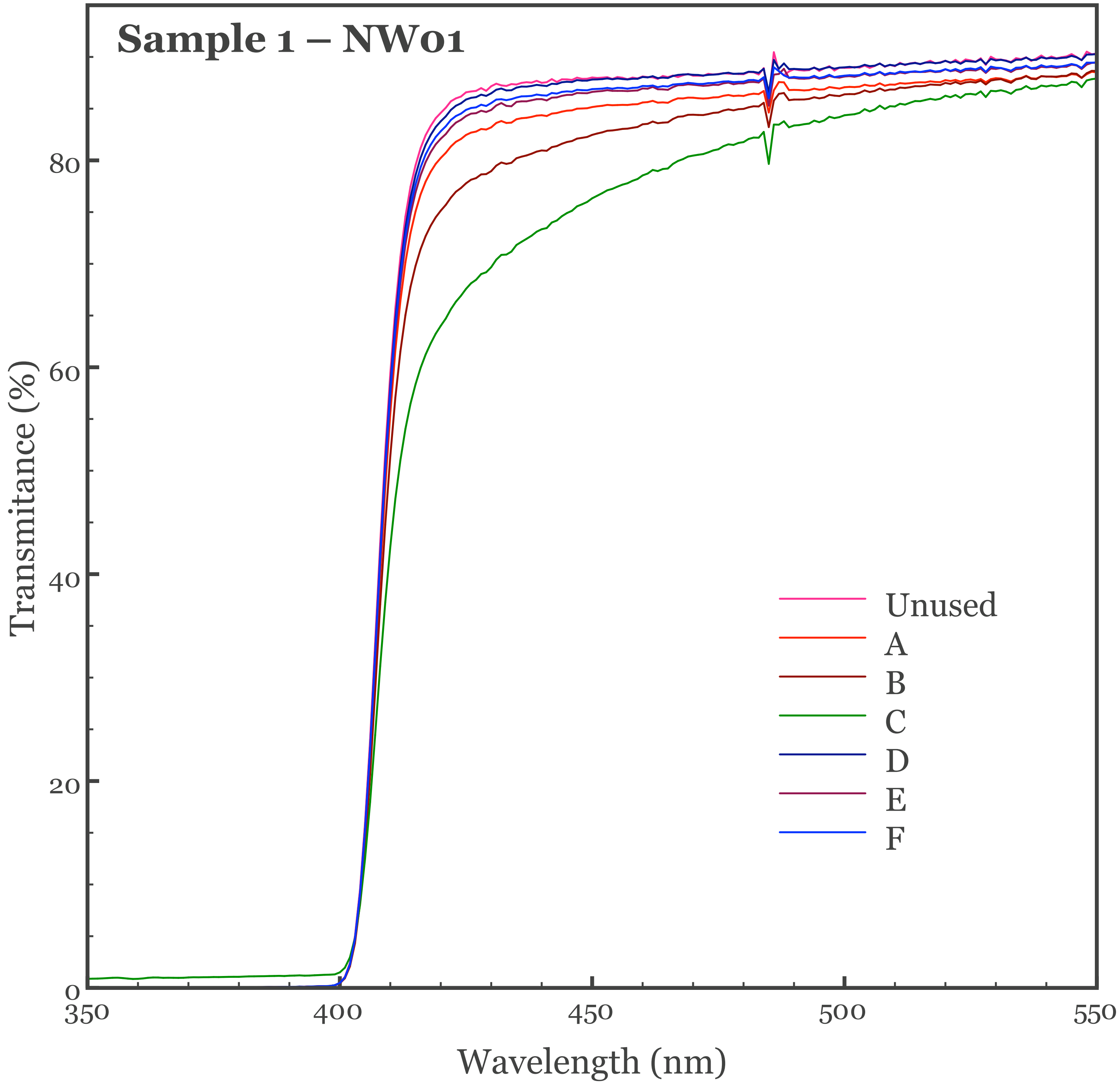
Farther from beam

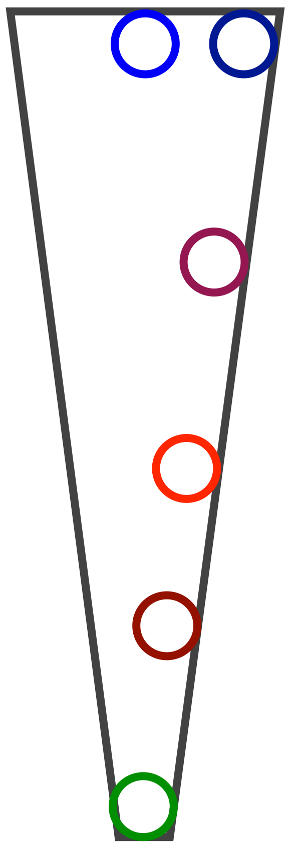


Closest to beam

- Transmittance is measured perpendicular to the scintillator surface.
- Different positions on the scintillator.
- Available data for scintillator replaced on shutdowns 2009 and 2010.
- Data includes different positions for all the pieces and sets of different dates for a few of them.

Spectrophotometry



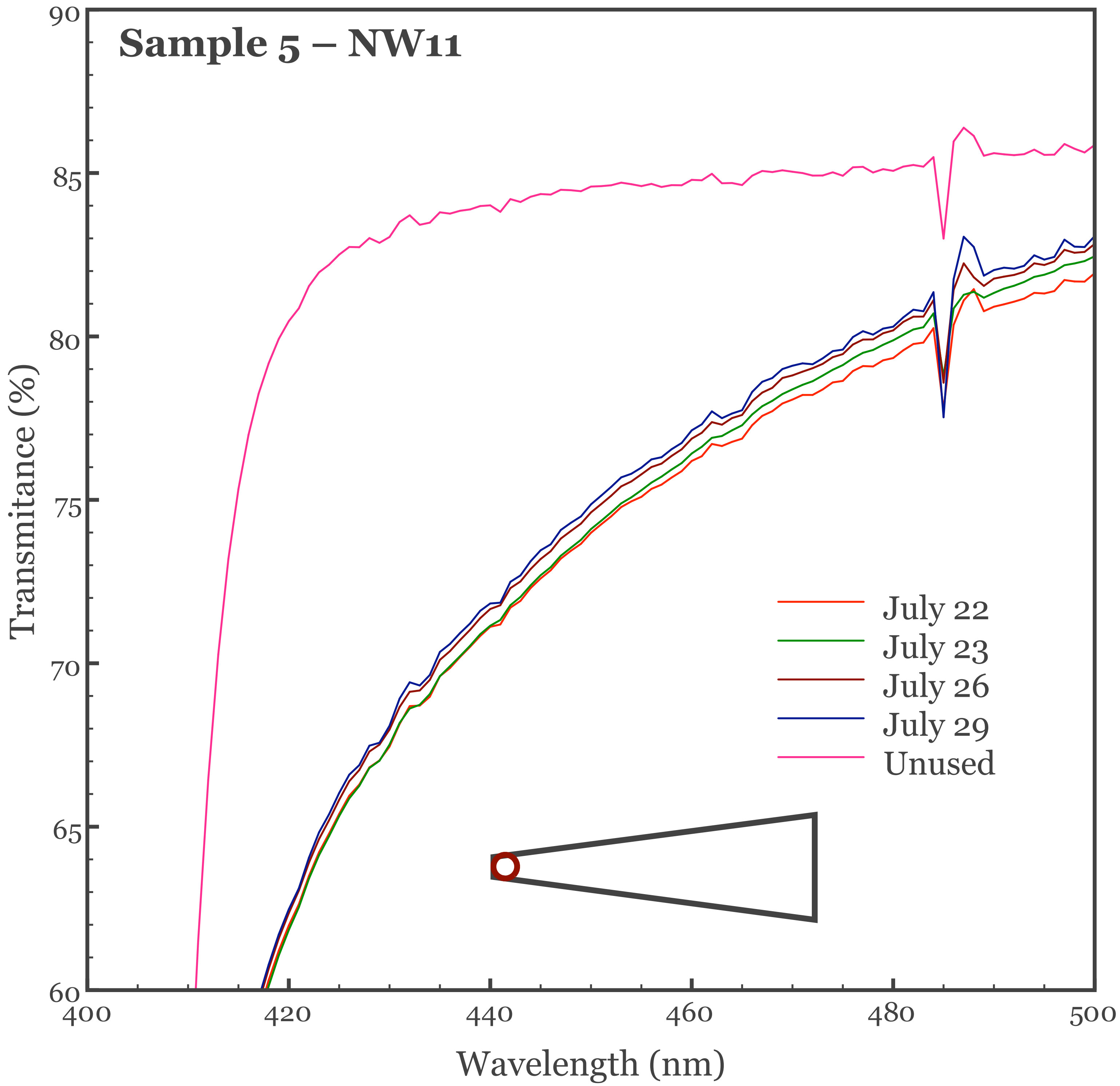


- For the same wedge on different positions: the most damage is observed at the point closest to the beam pipe.
- All the pieces are consistent with this behavior.

Spectrophotometry

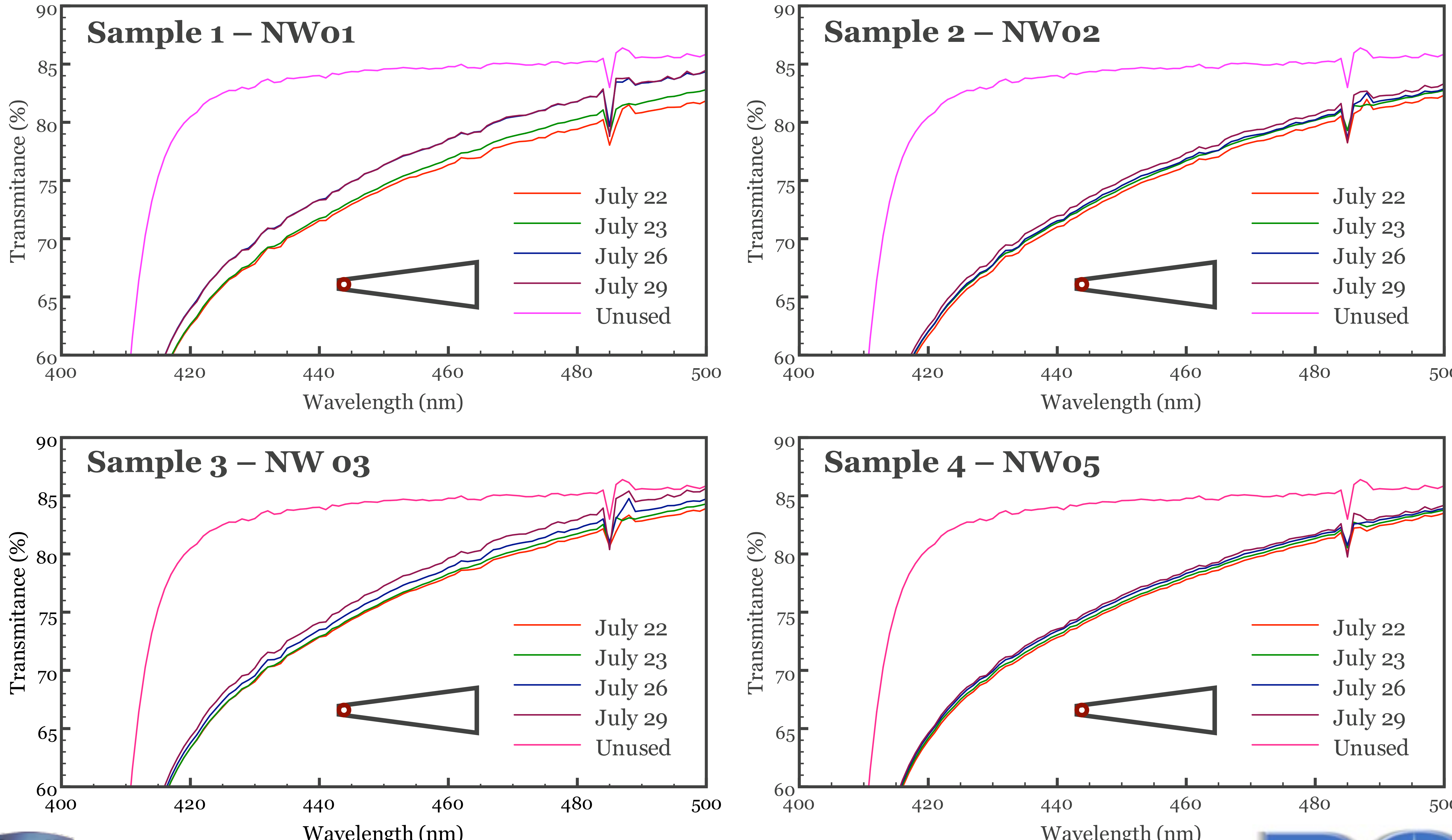
- 2010 Spectrophotometry measurements taken within 5 days of last beam.
- This is the fastest luminosity scintillator has ever been taken out of the detector.
- On the 1st day, only 5 pieces were measured due to laboratory time constraints.
- Measurements for these five pieces allow to see some annealing effect (According to literature, the maximum amount of annealing takes place on a time scale of hours to days).
- All 48 pieces measured on the next days.

Annealing



- In all analyzed samples: transmittance show increase with time.
- However, the annealing seen in these measurements is not a large effect.
- Annealing has a limit (separation from the "unused" curve gives an idea of the real damage).
- Not the only way to keep a healthy luminosity measurement.

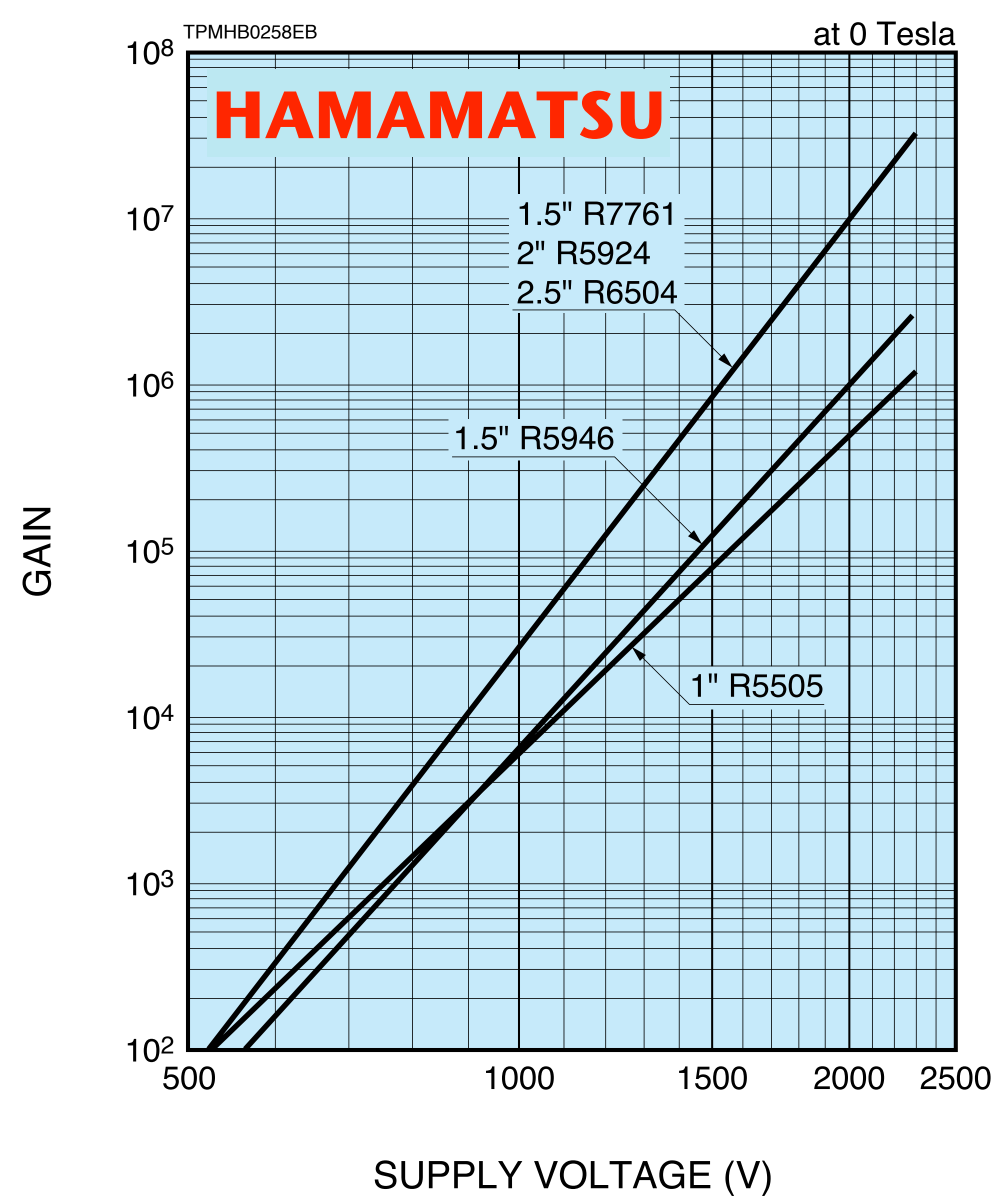
Annealing


Sample 1 – NW01
Sample 2 – NW02
Sample 3 – NW 03
Sample 4 – NW05
Transmitance (%)
Wavelength (nm)
90
85
80
75
70
65
60
400
420
440
460
480
500
July 22
July 23
July 26
July 29
Unused

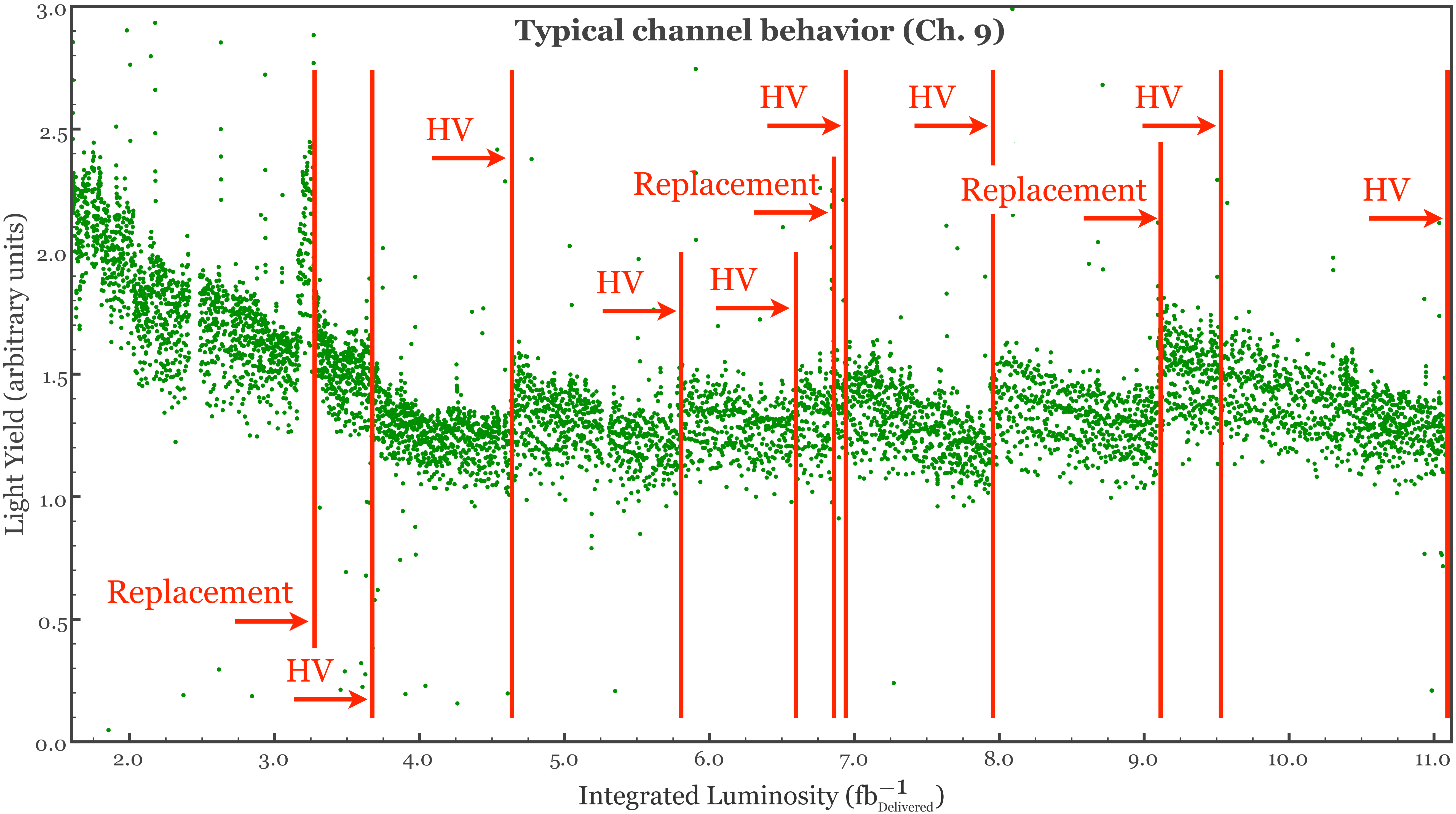
HV Adjustment

- When the drop in the light yield has reached some limit, it is compensated by a HV adjustment.
- Increases the gain in the PMT.
- Individually set for every channel.

Typical Gain Characteristics



HV Adjustment



Summary

- The switch to the dry air purge has allowed the scintillator to anneal in the LM during periods without beam.
- Spectrophotometry results show that the worst damage to the scintillator is near the beam pipe, as expected, and that most annealing has occurred before the earliest measurements were made.
- The Luminosity Monitor is bombarded by radiation but maintenance keeps the luminosity measurement within a 0.5% stability range.