WBS 2.3
Wavelength Shifting Fiber Breakout Session

June 4, 2007

Carl Bromberg

Michigan State University

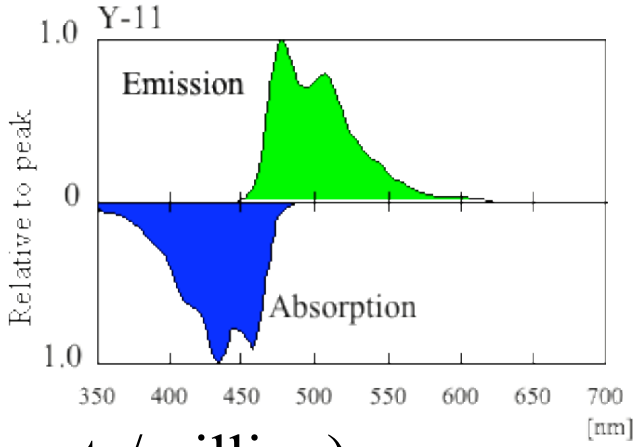
WLS fiber Technical Design

- Factors affecting choice of fiber
  - Cost - small diameter costs less per meter
  - Loop - perfect mirror, small diameter flexible for safe U-bend
    but, difficult to handle if too small
  - Performance - optimize fluorescent dye concentration

- Settled on a WLS fiber diameter of 0.7 mm
  - Baseline scintillator & WLS dye gave ~30 p.e. at far end of cell
  - 0.8 mm fiber is 19% more expensive and harder to bend safely
  - 0.6 mm fiber is too fragile for module assembly

WLS fiber Technical Design

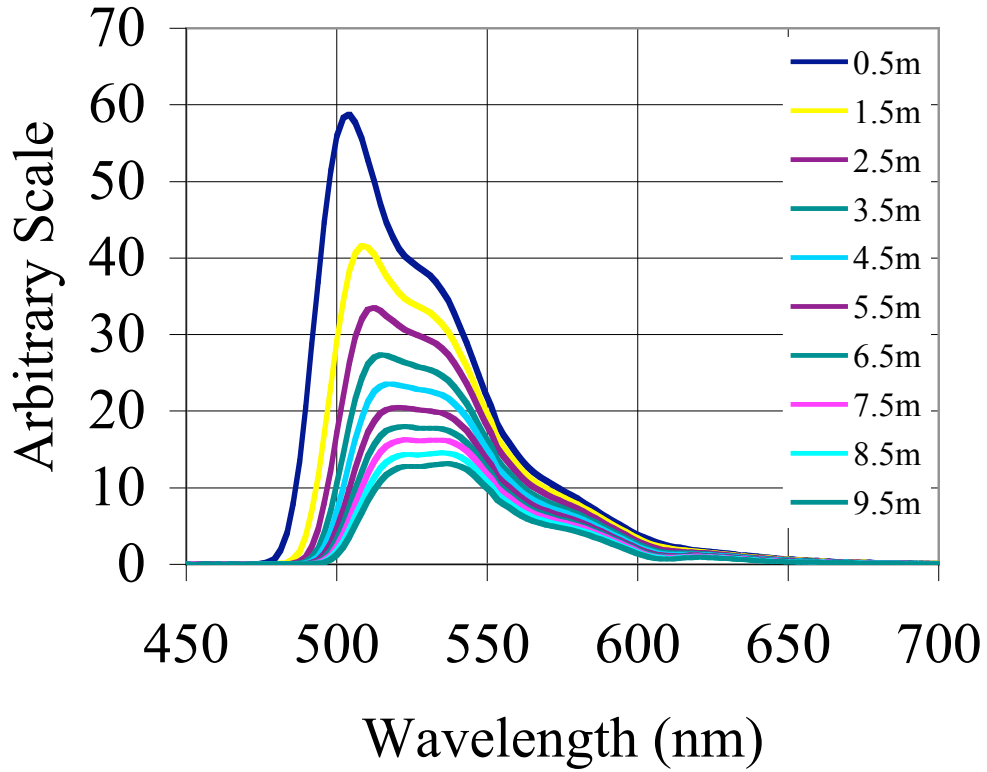
- Factors affecting choice of WLS dye concentration
  - absorption of blue scintillation light
  - dye self-absorbs its blue/green emissions
  - high QE >80% for green/yellow light
  - long 15.5 m cell
  - optimize for light from far end of a cell



- Optimize K27 dye concentration (100's of parts/million)
  - investigated various diameters, with 150 - 300 ppm of K27 dye
    - spectral response vs. fiber length, characterize attenuation length
    - signal yields in a simulated NOνA cell
    - signal yields in a liquid scintillator filled NOνA cell
    - R&D continuing; data suggest dye content of > 300 ppm

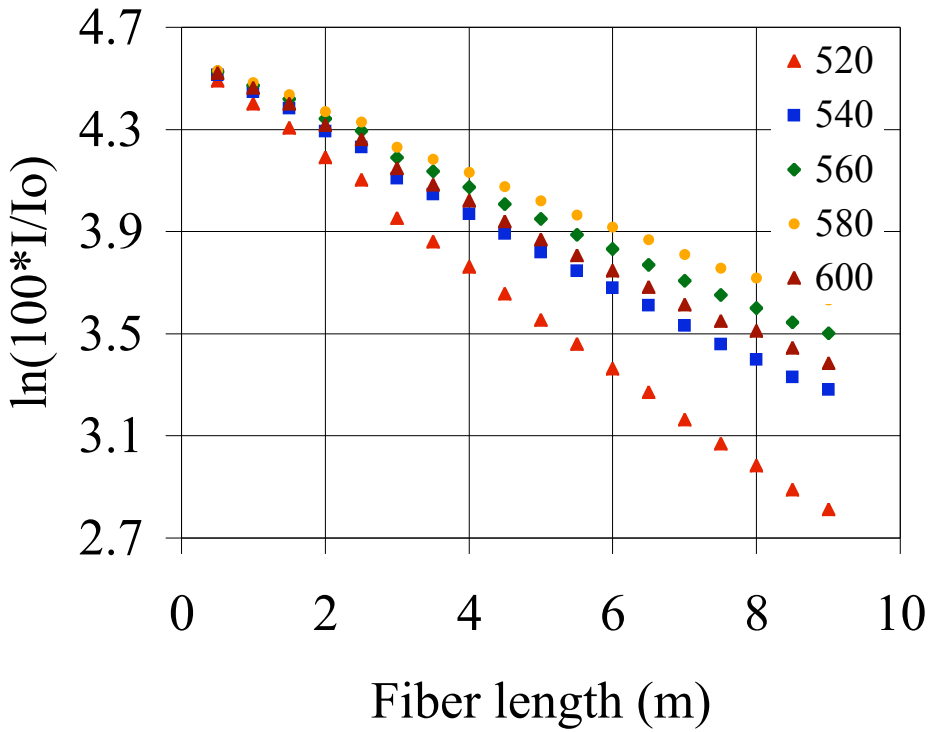
Spectral analysis

- Scan LED over fiber analyzing light output
- Light is strongly attenuated in fiber for $\lambda < 520$ nm
- APD has QE > 80% at long wavelengths



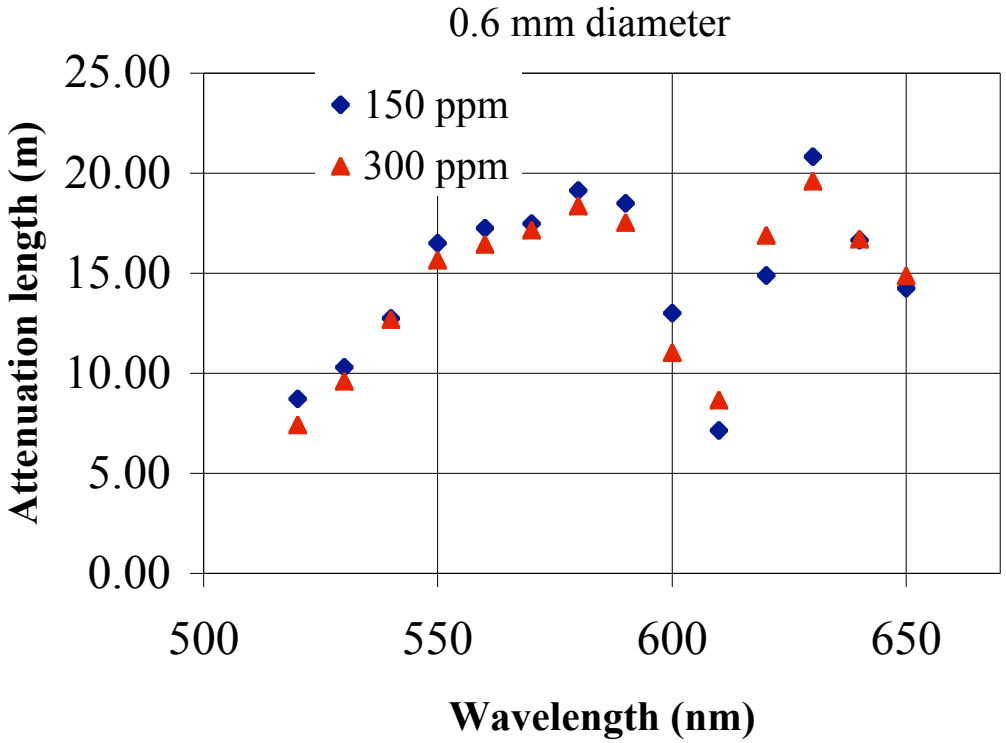
Fixed wavelength attenuation

- Exponential for $\lambda > 520$ nm
- Nearly independent of dye content for $\lambda > 560$ nm



Attenuation lengths

- Attenuation length vs. wavelength

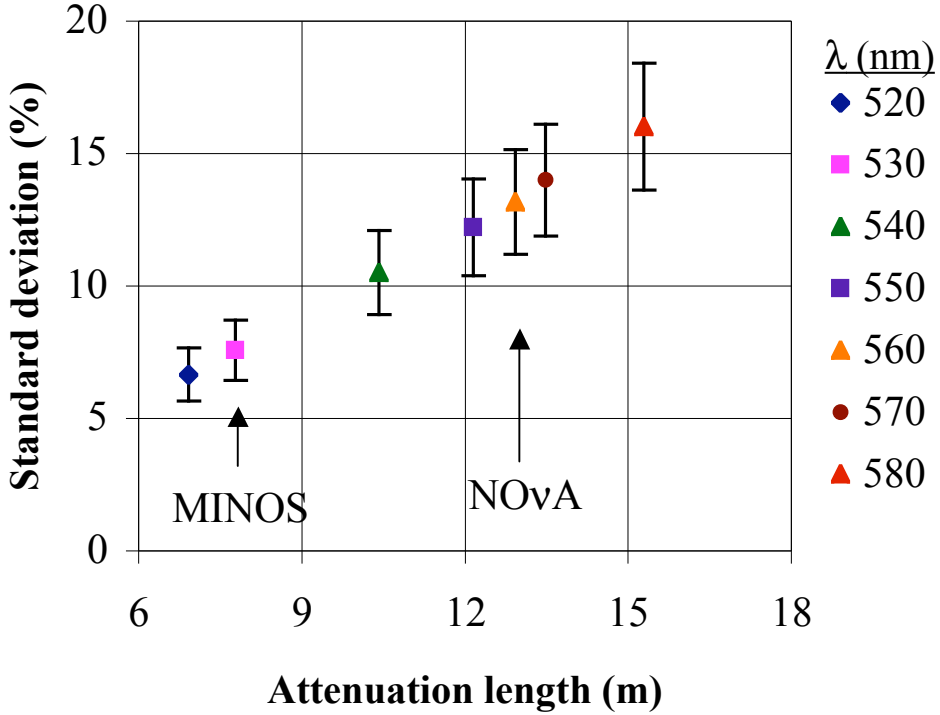


  - Attenuation length can exceed 15 m
  - Polystyrene absorption "peak" at 610 nm

- However, attenuation length is sample dependent
  - 250 ppm samples peak attenuation length of 13 m.
  - Kuraray QC data confirmed effect, no explanation (fluctuation)

WLS fiber variations

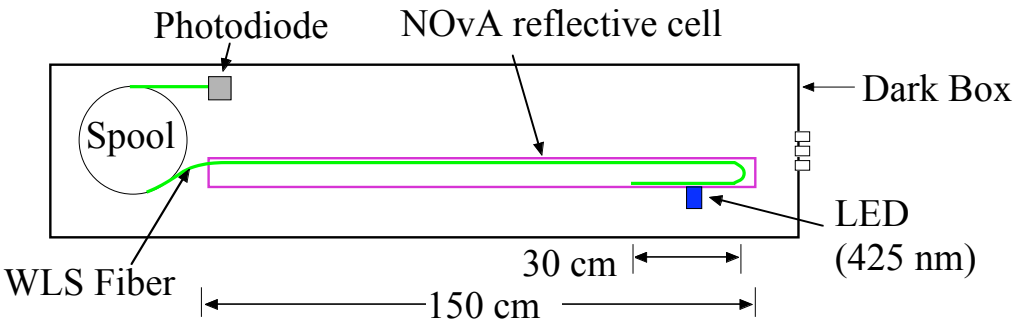
- Based on limited statistics from the Kuraray QC data, make an estimate of the attenuation length variations.
- Fractional standard deviation in attenuation length rises with the attenuation length (and wavelength) in the relevant region.



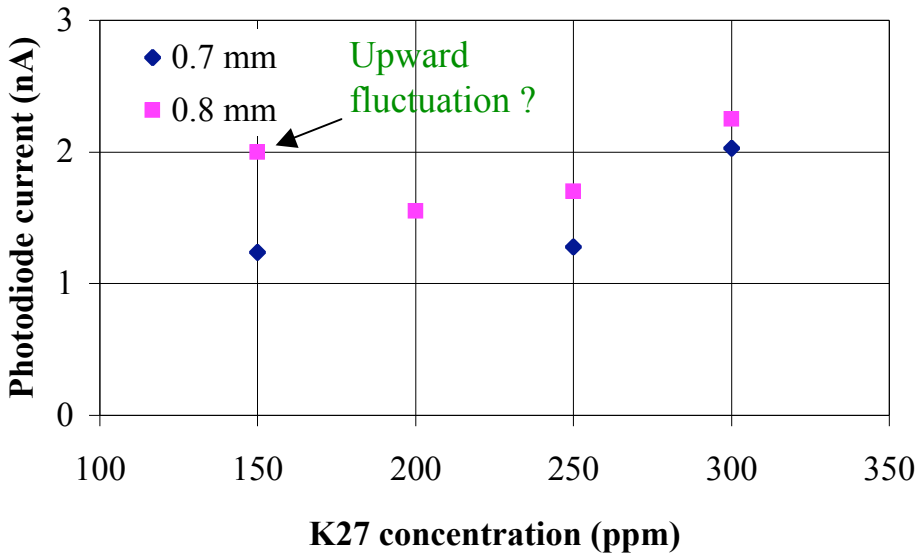
- Expect attenuation length σ in the 12-13% range.

WLS Fiber in a NOvA cell

- Simulated NOvA cell
  - 16 m fiber loop in a reflective PVC cell
  - photodiode detector
  - 425 nm LED illumination



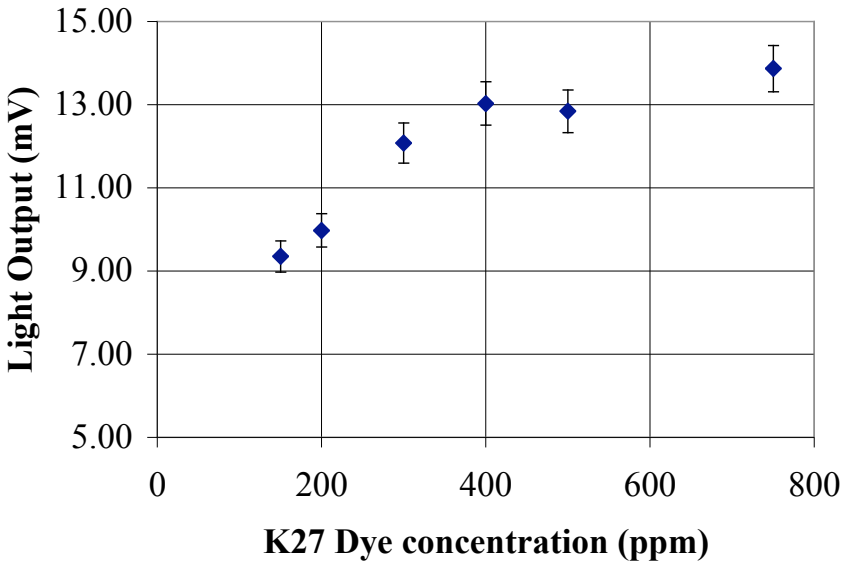
- Results
  - 300 ppm gives largest signal
  - short attenuation length of 250 ppm fiber reflected here



- More fiber is in hand
  - ~5 km each, 150 - 750 ppm
  - obtaining light yields
  - evaluating variability

Latest Kuraray QC data

- Kuraray will provide QC data.
  - Light output measurements on 0.7 mm fiber
  - We will verify in NOvA cells
  - Light output seems to plateau at about 500 ppm
  - For comparison, MINOS 1.2 mm fiber used 175 ppm.
- Attenuation vs. wavelength
  - Normally Kuraray doesn't provide spectral information
  - NOvA will ask for this QC data to encourage long attenuations lengths and relevant wavelengths



Fiber survival

- All tests show that the fiber will not degrade in the scintillator
  - Claddings are insoluble in liquid scintillator - double barrier protecting core polystyrene.
  - NOνA tests with a 6 cm diameter coil of fiber in 50% pseudocumine scintillator for two weeks at 42 C showed no transmission loss
  - Larger coils of heated scintillator are being tested. Early results (better stability needed) consistent with no loss over 2 months.
  - More information in following talk by Dan
- Curvature capabilities
  - Kuraray begins to see transmission loss for bend diameters 40 times the diameter of S - type fiber, attributed to core PS cracking.
  - NOνA bend diameter is 85 times the fiber diameter (0.7 mm fiber, 60 mm diameter bend)

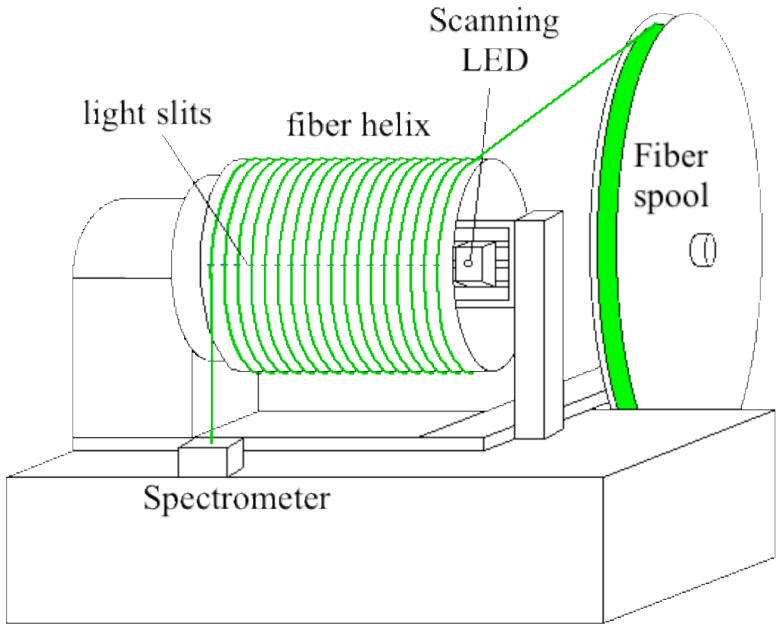
Costs and Schedule

- Bid Process
  - Kuraray proposal, was based upon their MINOS experience. NOνA WLS Fiber requirements are reflected in the proposal.
  - Kuraray quoted a cost ($0.63/m) for the 0.7 mm fiber in a quantity of 18,000 km with provisions for fluctuations in exchange rate and transportation cost.
  - Bicron (Saint Gobain) refused to bid; poor attenuation length.
- Delivery, QA, and storage
  - Kuraray fiber is delivered monthly to Michigan State University over a 4 year period with a Q4-FY08 slow startup, followed by a continuous delivery of ~ 4500 km/year
  - QA is performed and fiber is stored, location TBA (air-conditioning not essential), until needed by module factory
  - Shipped to module factory in original crates ready to install

WLS Fiber Quality Assurance

- Goals
  - One LED to monitor/calibrate
  - Minimize fiber handling
  - Normalized spectra and attenuation lengths
  - Return fiber to spool without damage
  - Design fiber scanner similar to ones MSU built for CDF and ATLAS
- Procedure
  - polish end of the fiber
  - unwind onto a scanning drum
  - scan LED with spectrometer readout
  - analyze attenuation immediately
  - investigate any anomalies
  - local database updated
  - rewind and store in original crates

fiber scanner



Summary

- Technical Design
  - WLS fiber diameter is 0.7 mm
  - R&D on dye concentration complete by the end of 2007
  - QA plan evolved from WLS fiber R&D
- Costs: fiber ($11.34M), QA 4 years ($1.0M)
- Schedule
  - Specify fiber for Integration Prototype ND in Q1 FY08
  - Specify fiber for Near & Far Detector in Q3 FY08
  - Fiber multiyear contract placed in Q4 FY08
  - QA tunes up with IPND fiber in FY08
  - Full production speed FY09-12
- No CD-3a items in this WBS