WBS 2.2 Plenary
Liquid Scintillator

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Liquid Scintillator for NOvA

The NOvA detector requires 9.4 kilotons of liquid scintillator

Baseline Liquid Scintillator

"Baseline Fluors"

component	purpose	mass fraction	volume (gal)	tot mass (kg)
mineral oil	solvent	95.79%	2,810,674	9,074,478
pseudocumene	scintillant	4.11%	117,526	389,720
PPO	waveshifter #1	0.091%		8,576
bis-MSB	waveshifter #2	0.0013%		120
Stadis-425	antistatic agent	0.0003%		28.4
tocopherol (Vit.E)	antioxidant	0.0010%		95
Total		100.0%	2,928,200	9,473,017

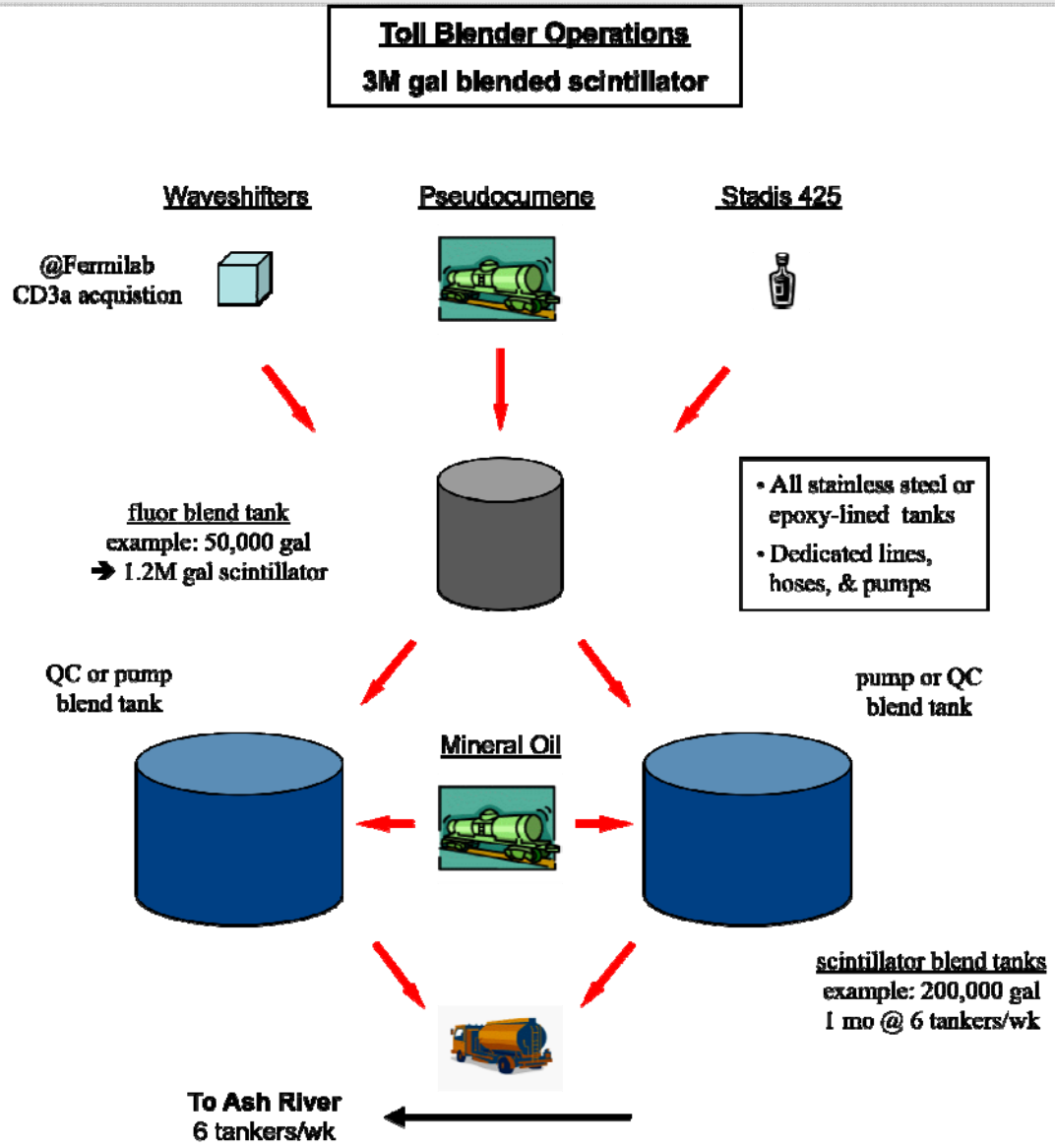
Detector: volume mass

The advantages of this mixture include:

- stability
- low cost
- low toxicity
- high flashpoint
- low potential as an environmental hazard
- safe for WLS fiber and PVC over lifetimes exceeding this experiment

Requirements documents exist for all components, leading to an ultimate requirement of 20 pe from (scintillator + PVC + fiber + APD)

Production Model



Where We Are

- **Components:** R&D has solved all basic problems
  - waveshifter PO issued (June 3, 2009) to Curtiss Laboratores
    - > multiple QC tests by producer and at Fermilab
  - pseudocumene: two acceptable producers, US and China; shipping makes Chinese pseudocumene more expensive
  - mineral oil: 4 companies with oil that meet requirements (attenuation length > 4m, acceptable density, viscosity)
    - Renkert Oil (Renoil 70-T)
    - Penreco (Parol 60 C)
    - Sonneborn (70, 70A)
    - Duoprime
- **Blending:**
  - large numbers of 1 gal and 5 gal batches produced at IU
  - 4,500 gal blended at Fermilab
  - 3 visits to toll blenders in Chicago (Kinder Morgan, Lambent, Hydrite) interested in blending 15,000 gal for IPND as test of production methods

Liquid Scintillator QC

Liquid Scintillator QC is designed to answer 4 questions:

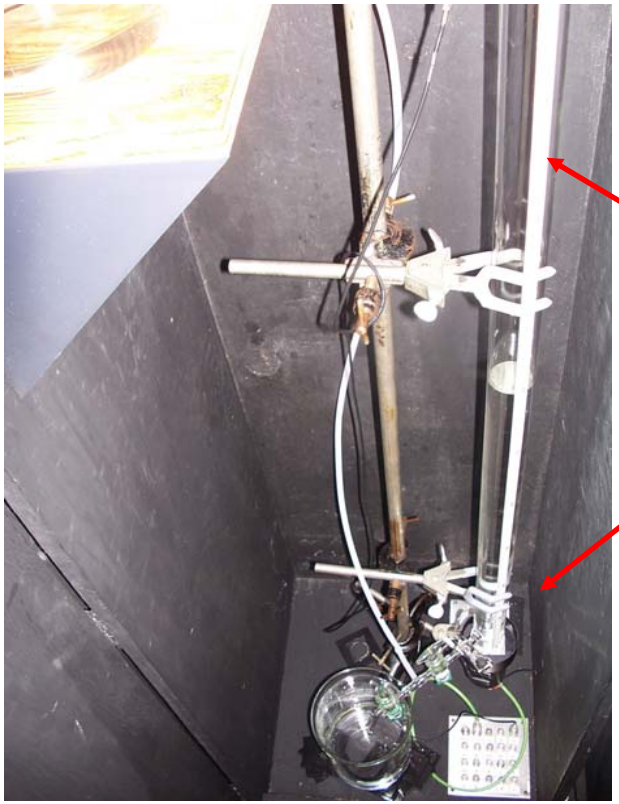
- Oil/scintillator attenuation length
  - Is the oil clear enough so that it can be blended into scintillator that meets NOvA's requirements?
- Chemical composition of liquid scintillator
  - What is the mass fraction of the 3 main components of scintillator: pseudocumene, PPO, & bis-MSB?
- Light output of liquid scintillator
  - Of primary importance, does the scintillator meet the NOvA light output requirements?
- 4th (Sanity) Check
  - Has enough anti-static agent been added to mitigate fire hazard? This check is accomplished simply.

III A. Mineral Oil Attenuation Length

Mineral oil QC tests oil transmission at 420 nm.
It is based on a commercial Lovibond Tintometer, calibrated by the IU spectrophotometer

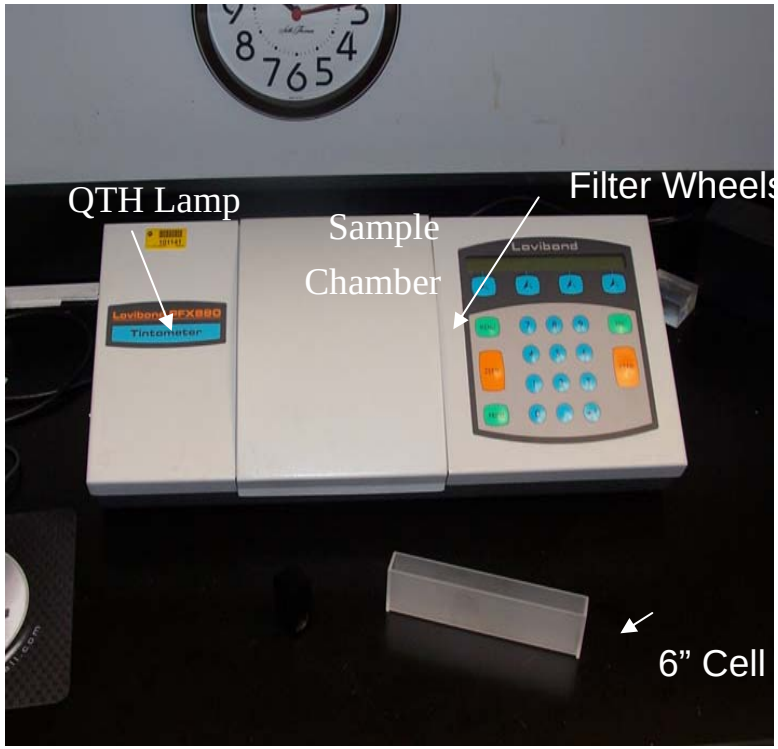
IU Spectrophotometer

measures light through graduated column



tintometer

measures light transmission through 6” cell

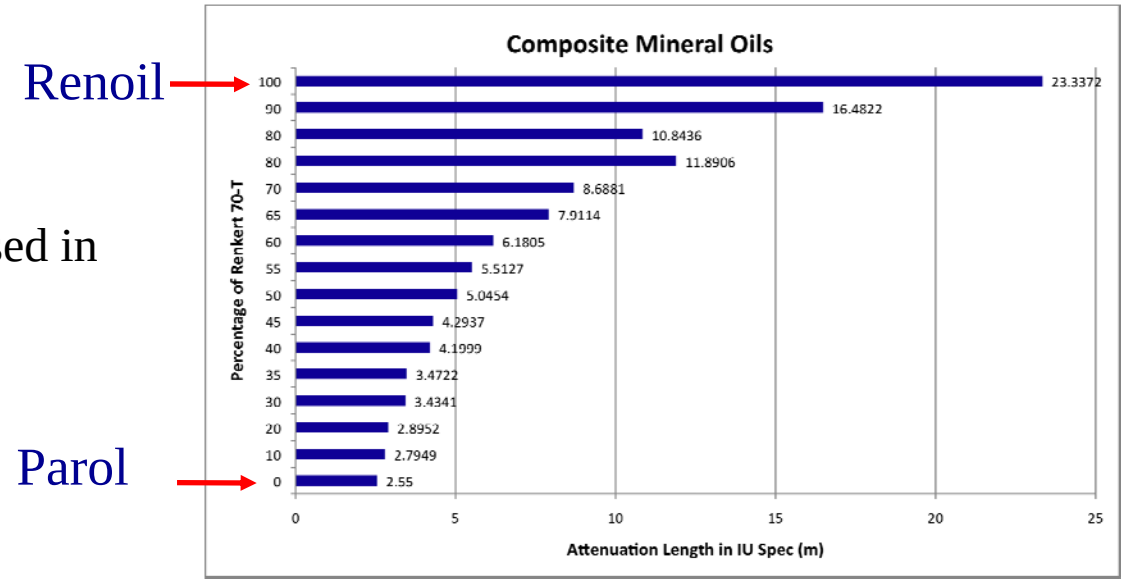


III A. Mineral Oil Attenuation Length

Program:

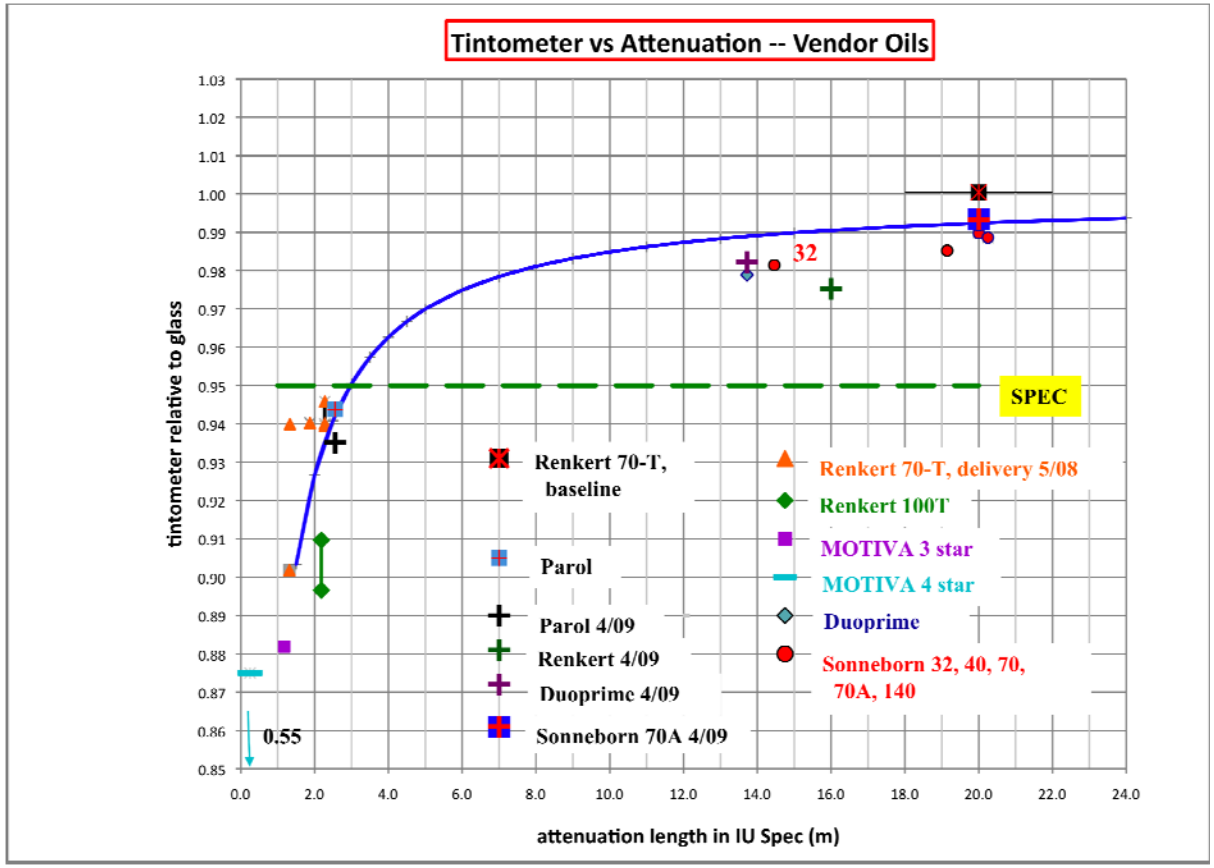
- calibrate attenuation length vs. tintometer transmission relation with a set of blended mineral oils having a range of attenuation lengths
- set the minimum acceptable attenuation length and demonstrate that mineral oil meeting this spec yields blended scintillator that meets the light yield requirement for NOvA
- translate attenuation length spec into tintometer transmission ratio
- show that the tintometer spec differentiates acceptable from unacceptable mineral oils

Composite mineral oils used in tintometer tests



III A. QC: Mineral Oil Attenuation Length

Strategy: Set requirement to exclude Parol. By showing that Parol 60C can be blended into scintillator that meets the NOvA light yield req's, oils longer attn.len. also meets the req's. Further, fluctuations will not resultin taking oil that fails to meet the light yield req.



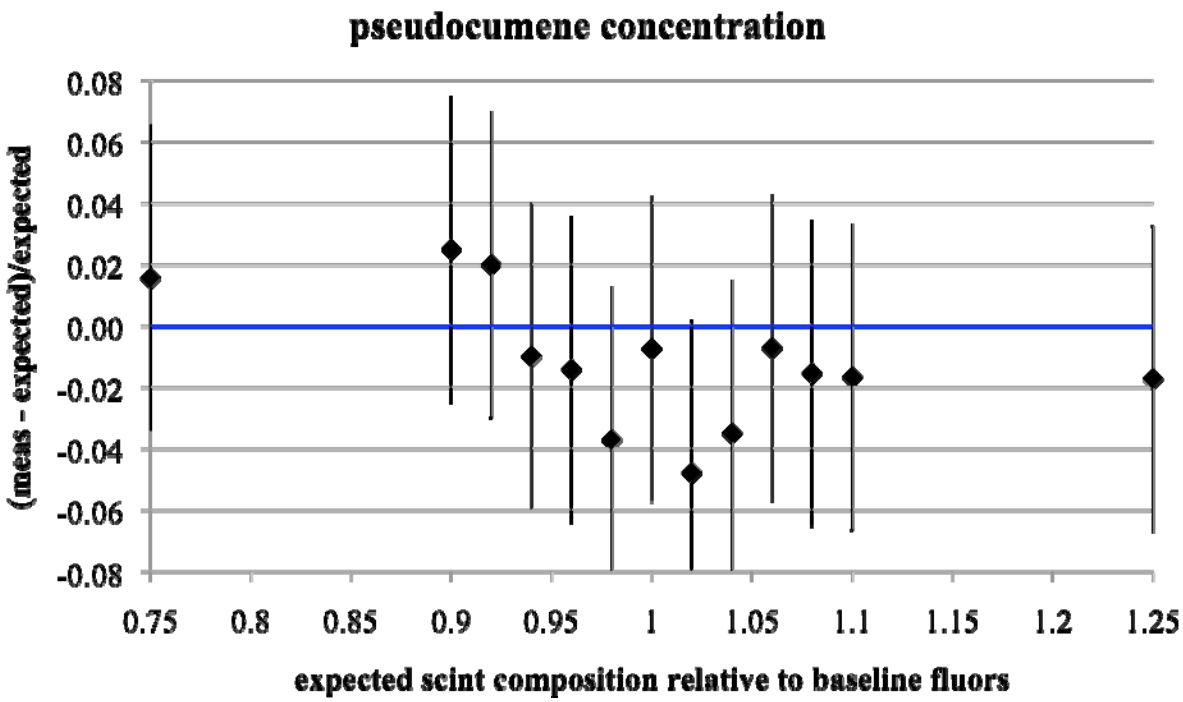
Scintillators	Light Yield (pe's)
Renoil 70T-based	33.4
Parol 60C-based	27.4

Requirement: 22 pe's

Conclusion:
Parol 60C can be blended into scintillator that meets the light output requirement for NOvA

Chemical Composition

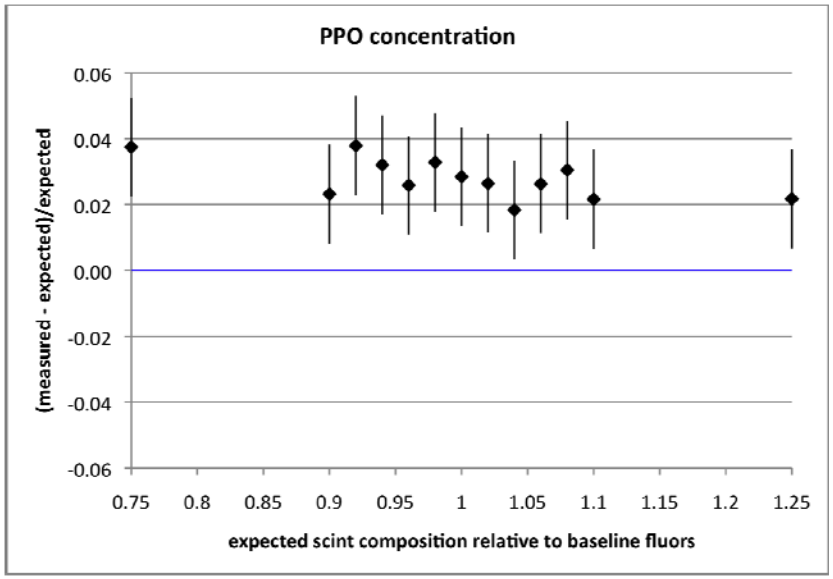
- pseudocumene mass density (kg/l) measured to a precision of ~5% at IU Chemistry by GCMS (gas chromatography/mass spectroscopy)

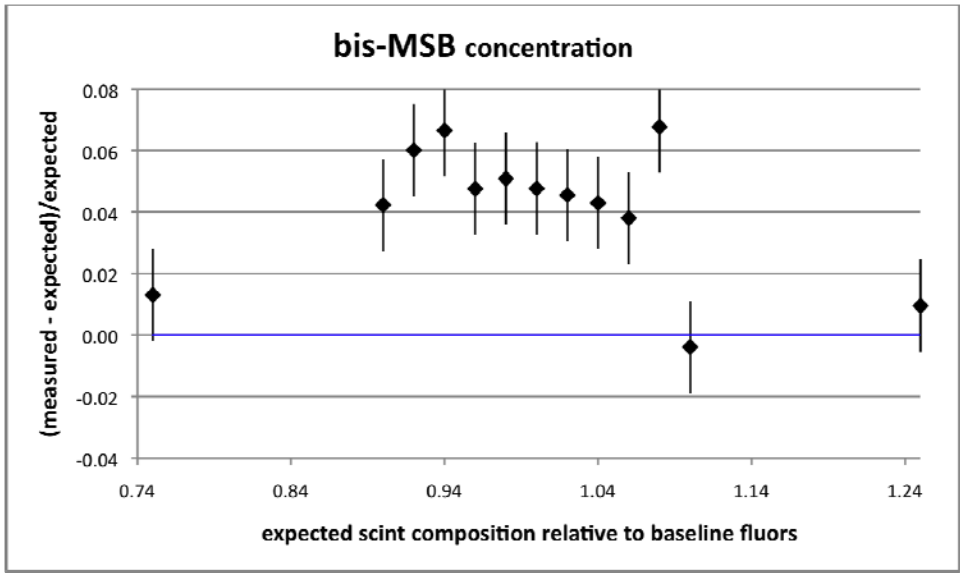


pseudocumene: scintillant

Chemical Composition

- PPO and bis-MSB mass densities (kg/l) measured to a precision of ~2% at IU Chemistry by HPLC (high performance liquid chromatography)





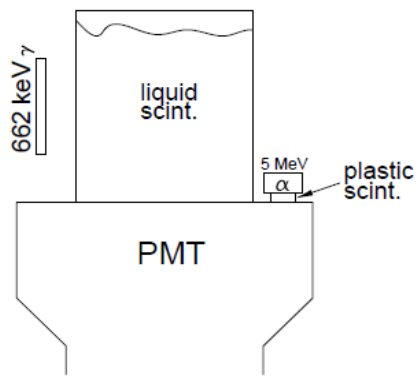
PPO: waveshifter #1

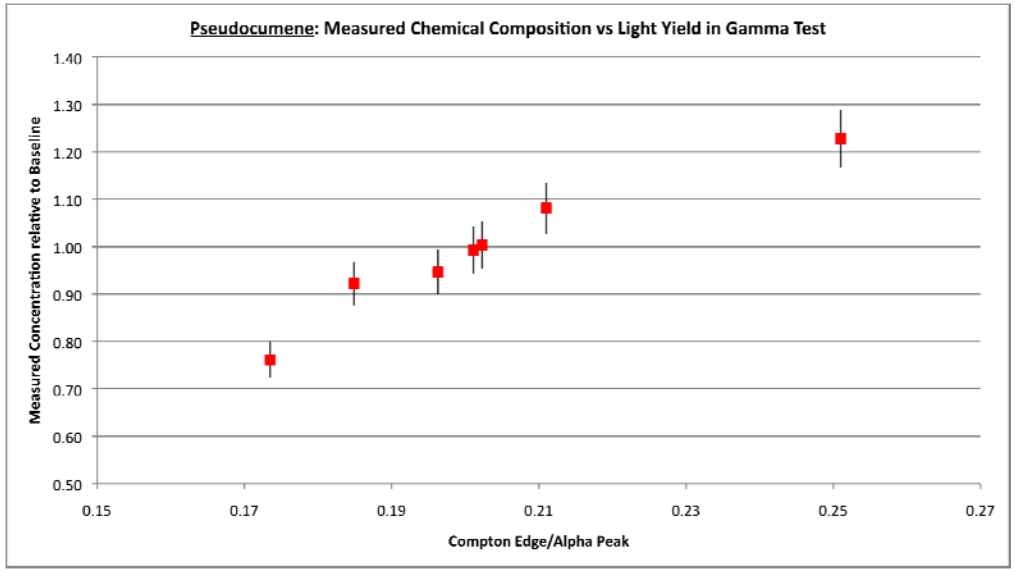
bis-MSB: waveshifter #2

Light Output

Does the scintillator have the light output expected for its composition?

gamma test apparatus:





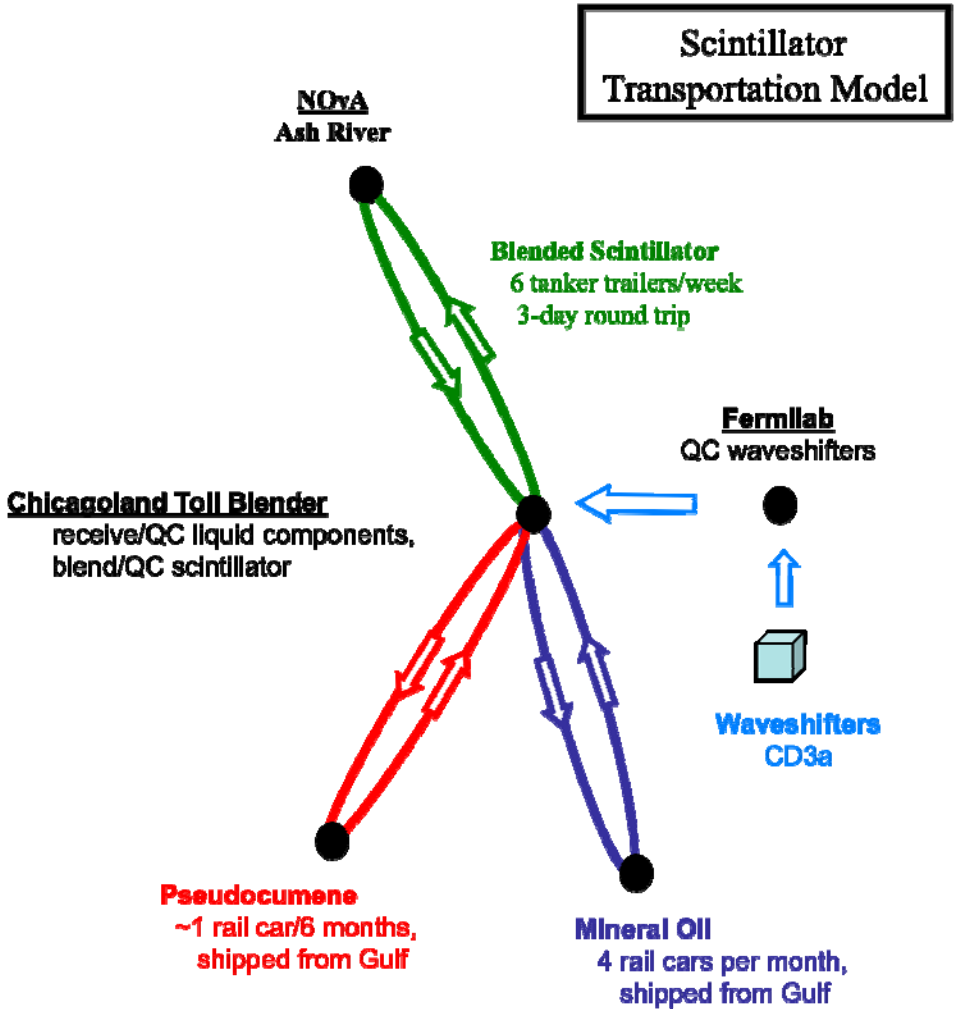
gamma test measures the Compton edge (gammas) relative to a fiducial Alpha peak. Metric:

(Compton edge/Alpha peak)

-- measures the expected light output of scintillator as a function of its composition

Alpha test abandoned when some radioactive materials off the Au foil

Transport



model requires
12 tankers/6 drivers
to transport scintillator
to Ash River

Summary

1.2, 2.2	Overall Design Status – Scintillator	>90%. Missing designs are straightforward to complete, no show-stoppers expected	
1.2.10	Production Scintillator Specifications		Mufson
1.2.10.3	Scintillator specifications completed	composition, light yield requirements, & transmission requirements specified	
2.2.1	Mineral Oil		
2.2.1.5	Mineral oil production & delivery	vendors identified that can meet requirements	
2.2.1.6	QC-Mineral oil	transmission testing with tintometer and IU spec, vendor supplied report	Busch
2.2.2	Pseudocumene		
2.2.2.5	Pseudocumene production & delivery	vendors identified that can meet requirements	
2.2.2.6	QC-Pseudocumene	vendor supplied report	
2.2.3	Waveshifters and Stadis 425		Pla-Dalmau
2.2.3.5	Waveshifter production & delivery	waveshifter PO issued	
2.2.3.6	QC-Waveshifters	waveshifter QC understood	
2.2.4	Blending		Pushka
2.2.4.2.3	Production blending of fluor concentrate	methods understood, toll blenders to be identified	
2.2.4.2.4	QC-Production fluor concentrate	QC: transmission, composition, light yield	Karty, Bower
2.2.4.3.3	Production blending of scintillator	methods understood, toll blenders to be identified	
2.2.4.3.4	QC-Production scintillator	QC: transmission, composition, light yield	Karty, Bower
2.2.5	Transport		
2.2.5.2	Near detector scintillator transport	detailed plans await final construction schedule	
2.2.5.3	Far detector scintillator transport	detailed plans await final construction schedule	

- The overall design status > 90% complete
- Missing design elements straightforward to complete
- No showstoppers are expected