Progress and Development of T2K's 280m Near Detector

Jenna M. King
ID# 200221752

May 11, 2004

Dr. Randy Lewis,
Physics Academic Advisor,
Cooperative Education

Dear Dr. Lewis,

Having completed the second half of a double work term at TRIUMF, I am submitting my work term report for evaluation. Beginning on May 3, 2004 and ending on August 20, 2004, this was the third of four workterms I plan on completing.

I remained under the supervision of Dr. Akira Konaka and Dr. Stanley Yen and continued researching a near detector design for the T2K project. I assisted in the designing and prototyping of a 280m near detector that will be used as part of a long baseline neutrino oscillation experiment.

I have prepared a report, entitled "Progress and development of T2K's 280m Near Detector," outlining results discoverd since my last report and my current research into the design of the detector.

Sincerely,
Jenna King
ID# 200221752

Progress and Development of T2K's 280m Near Detector

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Work Term #3

Sept 2004

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Abstract

Research into the optimal design for the T2K 280m Near Detector has led to several candidate materials being selected. If it is decided that the detector should contain a gel rather than a liquid, a suitable gelling agent has been found. As well, a liquid scintillator and wavelength shifting fibre have been chosen. Research is now focused on the effects of age on these materials both individually and as they would be used in the detector. The scintillator, QuickSafe A, dissolves the polystyrene core of the wavelength shifting fibres but it may be a solvable problem. To fight mold and other biological growth in the detector, we have also found a satisfactory biological inhibitor.

1 Introduction

TRIUMF's Neutrino Group is currently doing research for the T2K project, an international collaboration of scientists whose aim is to learn more about neutrinos and neutrino oscillations. The T2K project will send a neutrino beam 295km from Tokai, Japan to the far detector, Super Kamiokande (Super K), in Kamioka, Japan. Such a long baseline is needed in order to determine the mixing angle and mass difference for electron and muon neutrinos.

1.1 The Near Detector

The neutrino beam, originating at the JHF-ν Proton Accelerator, will first pass through a near detector on its way to Super K. The purpose of the near detector is to determine the energy, flux, direction and composition of the neutrino beam so predictions can be made as to what to expect at Super K. Comparisons between the two detectors can be made as well. The near detector design is one part of the Canadian contribution and the focus of this paper. The near detector will ideally be a water-based scintillation detector; since Super K is a water-Cerenkov detector, having water as the main target of the near detector would reduce the uncertainties that would arise from having different nuclear targets. The scintillator will either be a liquid or a gel.

1.2 Research Goals

Finding the appropriate gelling agent is the first task that must be completed before using a gel is even a possible option. It has not been decided

whether a gel or a liquid would be more desirable. There are many arguments supporting either choice so research is being done for both options.

Since water is a quencher of scintillation light, a water-based scintillator is a challenging proposal. After researching a number of commercially available liquid scintillators, QuickSafe A has been chosen by the neutrino group as the best candidate. A plastic wavelength shifting fibre has also been selected. Since the detector is supposed to be in use for such a long period of time–a decade or more–the stability of the chosen materials over long periods of time becomes very important. Aging studies have been done on both the QuickSafe A liquid scintillator and the wavelength shifting fibres we would like to use.

Another concern that has arisen about the detector design is that the chosen mixture must be resistant to mold and other biological contamination. Mold has been seen growing in QuickSafe A and water mixtures so some sort of biological inhibitor must be included in the final scintillating solution.

2 Gelling Agents

2.1 Gels

In my previous report, "280m Near Detector Research for T2K Neutrino Oscillation Experiment", the gelling agents tested included Knox and Robertson's brand gelatin, Carageenan powder and the Water Crystals brand polyacrylate polymer [A.2]. Both the gelatin and Water Crystals turned opaque and separated into two distinct phases when mixed with any concentration of QuickSafe A. Carageenan was the best option at the time, producing an opaque but uniform gel that had little effect on the light yield. Many tests have been done to determine the effects of a gelling agent on the efficiency of the scintillator as well as to determine whether a gel would facilitate a higher or lower concentration of water should a gel be needed. I have since tested six new gelling agents with varying results. Many of the gels caused the water and scintillator mixture to become opaque while others formed precipitates or were nonuniform. All of the gels made with QuickSafe A and water also contain 2% Triton X-100, a surfactant that improves QuickSafe A's water solubility. The Triton X-100 contains PPO/POPOP at a concentration of 0.971g PPO and 0.029g POPOP in 50ml of Triton X-100.

2.1.1 Klucel Hydroxypropylcellulose

Klucel hydroxypropylcellulose is a thickening agent that comes in many types including types G, H and PR [A.7]. As the three types which seemed to most closely meet our needs, all three of these types were tested with QuickSafe A. While less than 2% by weight of the powder is needed to form a gel, the procedure for preparing gels from this power is quite complicated. Klucel powder is more soluble in cold water than in hot and one must first get the powder wet in a small amount of hot water (50°C) to avoid clumping. Then the remaining water can be added to bring your solution to the desired volume. For our purposes, the powder was mixed in the warm water and a mixture of water and QuickSafe A was added. None of the three types produced desirable results. While thick, transparent gels were made with only water, the addition of QuickSafe A caused all mixtures to separate into two phases.

2.1.2 Natrosol

Natrosol is a thickener commonly used in hair care products such as hair gel and shampoo. It is chemically modified hydroxyethylcellulose, manipulated to have high water solubility but with hydrophobic functional groups attached to the polymer backbone to make it tolerant of oils and surfactants [A.6]. Also in powder form, literature recommends using 2% by weight to thicken a solution. Mixtures of Natrosol and water did not form a sufficiently stiff gel and the resulting syrup-like mixture was uniform and transparent but quite yellow in colour. The addition of QuickSafe A once again caused the mixture to separate into two phases.

2.1.3 Stabileze QM

Another substance frequently used in the manufacturing of hair care products is Stabileze QM [A.5]. This powder must be dissolved in cold water and heated to 70°C for 40 minutes in order to hydrolyze. The acidic, hydrolyzed Stabileze QM is supposed to form a clear gel as soon as it is neutralized to a pH between 5 and 7. Using Sodium Hydroxide (NaOH) as the neutralizer produces the thickest gel. For the volumes we made, only a few drops of NaOH were required before the mixture stiffened. Stabileze QM required a significantly higher concentration of between 20% and 60% by weight. Unlike the previous gelling agents, when made with QuickSafe A and water the Stabileze QM formed a uniform, thick gel. However, the resulting gel is white and opaque.

2.1.4 RapiThix A-60

RapiThix A-60 comes in liquid form and is a pre-neutralized polymer [A.5]. Gelling immediately when added to water, the procedure for using RapiThix A-60 is simple and the result of adding between 0.5% and 1% by weight of the polymer is a creamy, white gel. Like Stabileze QM, mixtures of water and QuickSafe A with RapiThix A-60 remain uniform but are quite opaque.

2.1.5 Aculyn

Aculyn 22 is a liquid rheology modifier with high aqueous thicking efficiency [A.4]. Initially at a pH of 3, Aculyn 22 must also be neutralized to a pH of above 7 in order to form a gel. Aculyn 22 and water form a clear, viscous gel at concentrations between 1% and 4%. Mixtures made with QuickSafe A are only slightly cloudy but remain syrup-like and do not form stiff gels. We also tried 2% Aculyn 60 by weight, a nonionic rheology modifier. However, this mixture immediately separated into two phases.

2.1.6 Carbopol EZ-3

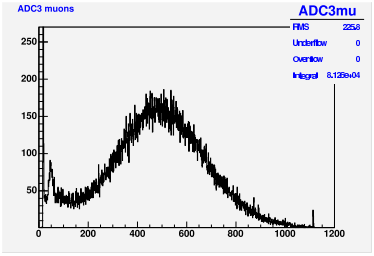
Needing only 0.6% by weight to be effective, Carbopol EZ-3 is another hydrophobically modified polymer that was tested [A.3]. Commonly used in car polishes, the viscosity of Carbopol EZ-3 is also pH dependent with the ideal range for a thick gel being between pH 5 and pH 10.Carbopol EZ-3 is quite dangerous to work with in powder form with both contact and inhalation dangers but once it is in gel form there is little concern. The cloudy mixture clears when it is neutralized and the clarity of the final gel is highly sensitive to the amount of NaOH added, not enough and the gel will not clear up enough, too much and a precipitate becomes suspended in the gel. At the appropriate pH, the gel is relatively clear and transparent. By experimenting with different procedures of making the gel, we found our best results came by combining the Carbopol EZ-3 and water as one phase, the QuickSafe A, surfactant and NaOH as another and adding a few millilitres of each phase on an alternating basis, stirring occasionally and carefully to avoid the formation of air bubbles until the desired volume is reached.

2.2 Best Candidates

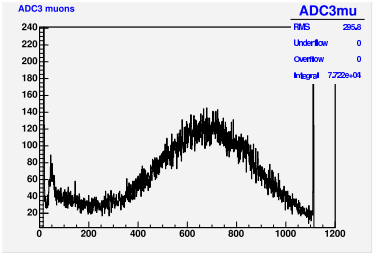
Similar gels with QuickSafe A and water were made with the best four of the six gelling agents (Stabileze QM, RapiThix A-60, Aculyn 22 and Carbopol EZ-3)[B]. The samples were tested one at a time in a 120 MeV/c muon (μ^+)

beam using our existing apparatus and three wavelength shifting fibres in each of the four caps.

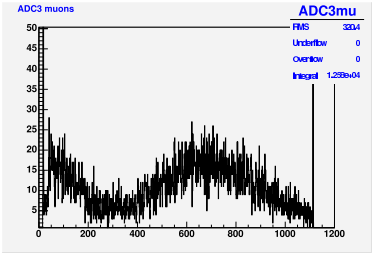
The two most promising thickeners based on the properties of the gel and results of the beam test are Aculyn 22 and Carbopol EZ-3, both acrylic polymers. The Carbopol EZ-3 is generally a thicker mixture while the clearest gels with Aculyn 22 are more syrup like. An argument for the use of a syrup or thinner mixture would be that the detector could then easily be drained and the scintillator replaced or changed. This would not be possible with a thick gel. Aculyn 22 showed good results in the beam test [Fig:1] but our focus is now on Carbopol EZ-3. Adding Carbopol EZ-3 to a Quick-Safe A and water mixture did not affect the light output of the scintillator [Fig:2a,b] and forms a suitable gel that was tested with three WLS fibres.



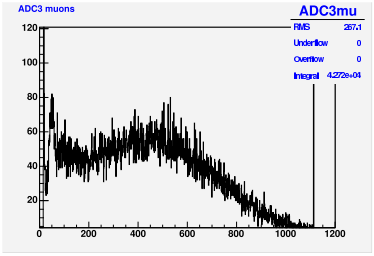
(a) Aculyn 22



(b) Carbopol EZ-3



(c) RapiThix A-60



(d) Stabileze QM

Figure 1: Beam Test Results

Another concern is that the acidic Carbopol EZ-3 will damage the wavelength shifting fibres that will be in the detector. Since it is mostly neutralized, the effect will be minimal but once again we are concerned with

effects over the long term. A set of nine fibres was made to be placed in a stock solution of Carbopol EZ-3 and water which has a pH of approximately 3. After taking an initial reading of the fibres in 100% QuickSafe A with a Co-60 source, the fibres were placed in the Carbopol EZ-3 stock solution and incubated. Because of this incubation, we were able to see what would be a comparable effect of the gelling agent in contact with the fibres for over a decade. Every week the fibres were removed from the heat and Carbopol EZ-3 solution and placed in vials of 100% QuickSafe A to test the efficiency.

After two weeks, there was no noticable deterioration. Both the shape of the Co-60 spectrum, and the number of counts in five minutes remained unchanged. Since the sample was incubated and at a much lower pH than it would be in gel form, this should be representative of the effects of Carbopol EZ-3 on the fibres over the course of the detectors lifetime. The effects of the mild acidity are negligible [Fig:2c,d].

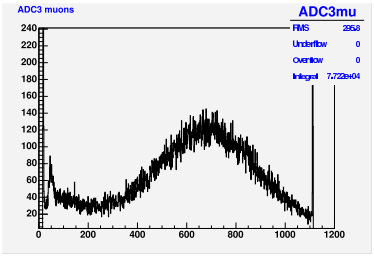
3 QuickSafe A and Aging Studies

3.1 Apparatus

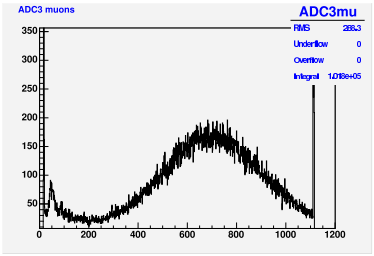
To test the efficiency of the scintillator, an apparatus was designed that encloses 22ml commercial, glass scintillation counter vials and can measure the light yield with a photomulitplier tube (PMT). Our sample scintillators can be made in these vials which are inserted completely into the black, plexiglas tube against a uv transparent layer leading to the PMT. A high voltage (-2000V) is applied to the PMT and the scintillator vial is exposed to ionizing radiation. The PMT collects the resulting scintillation light. By standardizing the procedure, direct comparisons between mixtures can be made.

3.1.1 Fibre Reading Vials

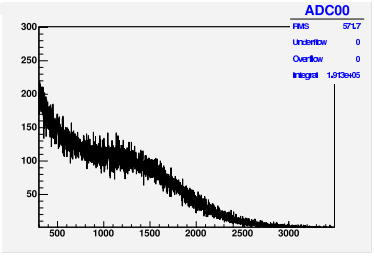
In order to use the same apparatus to read out the scintillation light with WLS fibres, modifications needed to be made. I drilled holes in the opaque caps of the glass scintillation vials of the correct size such that WLS fibres can be threaded through snugly (Drill Bit #59). The fibres are initially cut to approximately six centimeters in length and one end is sanded flat. An existing cap with a single hole functions as a sanding block for the fibres. They can be carefully inserted and sanded flush to the cap with varying grades of sandpaper, starting with #320, with little damage to the protective outer coatings. The fibres are then inserted into the cap so that



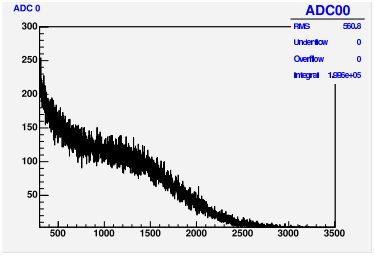
(a) 3 Fibres in QuickSafe A, Water and Triton X-100 with Carbopol EZ-3; 120MeV/c Muons



(b) 3 Fibres in QuickSafe A, Water and Triton X-100 without Carbopol EZ-3; 120MeV/c Muons



(c) 9 Fibres in Acidic Carbopol EZ-3 Stock Solution Initial; Co-60 Source



(d) 9 Fibres in Acidic Carbopol EZ-3 Stock Solution Two Weeks Later; Co-60 Source

Figure 2: Effect of Carbopol EZ-3 on Direct and Fibre Readings

the unsanded ends can be sanded flush with the cap. One must ensure that the fibres are still flush with the cap after it has been screwed on as that sometimes causes the fibres to shift slightly.

3.2 Materials

3.2.1 Wavelength Shifting (WLS) Fibres

The fibres we wish to use in the near detector are 1mm in diameter and consist of a polystyrene core with two thin film coatings, one of acrylic and the outermost of teflon. There are wavelength shifting chemicals suspended in the core of the fibres and the scintillation light that enters the fibre is shifted

into the green, and then travels down the fibre by total internal reflection. These fibres can be used to measure the light yield of a liquid scintillator. The known deterioration rate of the fibres is that the deterioration or aging rate doubles for every 7°C above room temperature at which the fibres are kept. Fibres kept one day at 7°C above room temperature should have aged the same as fibres that were kept at room temperature for two days. We can take advantage of this to perform accelerated aging studies and quickly determine how the fibres will fare over decades.

3.2.2 QuickSafe A

Finding an appropriate water-based, liquid scintillator poses a problem since most commercially available liquid scintillators have poor water solubility. We desire an active water target because it will simplify comparisons between the near detector and the far detector (Super K), which is water-Cerenkov. The scintillator we are testing, QuickSafe A [A.1], has relatively high water solubility. QuickSafe A is di-isopropylnapthalene dissolved in a non-ionic surfactant. QuickSafe A is safe to work with, it is biodegradable and has a flash point of over 150°C, however, it does dissolve polystyrene on contact so we need to determine the effects of the scintillator on the wavelength shifting fibres we wish to use and the rate at which they are damaged. By adding a small amount of another surfactant, Triton X-100, we are able to improve QuickSafe A's water solubility even more. Mixtures have been made with up to 70% water and tests are in progress to see if the mixture is stable over time and can produce a meaningful light yield. Our best mixture so far contains 19% QuickSafe A, 9.5% Triton X-100/PPO/POPOP and 71.5% water. This can be made with or without Carbopol EZ-3.

3.3 Aging Test Procedure

A Cobalt-60 gamma source, emitting two photons of 1.17MeV and 1.33MeV, is used for all trials. Once a sample has been inserted into the apparatus and the high voltage for the PMT is turned on, no data is collected for half an hour to allow the voltage and temperature of the tube to stabilize. While the sample is being exposed to ionizing radiation, data is collected for five minutes at a time and every reading is repeated three times with the sample vial removed and re-inserted each time to check on the reproducibility of the vial's placement. By looking at the average number of events recorded in three five minute trials, we can determine which mixtures are the most efficient and observe changes to efficiency over time.

To conduct a test on the effects of age on QuickSafe A and our wavelength shifting (WLS) fibres, I filled two vials with 100% QuickSafe A and took direct readings of each (i.e. reading the scintillation light directly through the glass bottom of the vial, with no WLS fibres present). A set of nine fibres was made and inserted into one of the vials, the other left untouched as a reference. By flipping our apparatus upside down, we could then take an initial reading of one of the samples with the set of fibres-a fibre reading-and then both the sample with the fibres and the reference are allowed to sit for one week's time under identical conditions. The room was temperature controlled, always at 22℃. After a week, the fibres were momentarily removed, and a direct reading was made of both the reference scintillator as well as of the scintillator that has had fibres sitting in it. Two fibre readings were done, one with the fibres in the scintillator it has been sitting in for the week and another with an equal volume of fresh scintillator that has not been used before. The four readings were done once a week for 5 weeks. We hope the tests results help us to differentiate between the effects of age on the fibre as well as the scintillator.

3.3.1 Fibre Aging Test

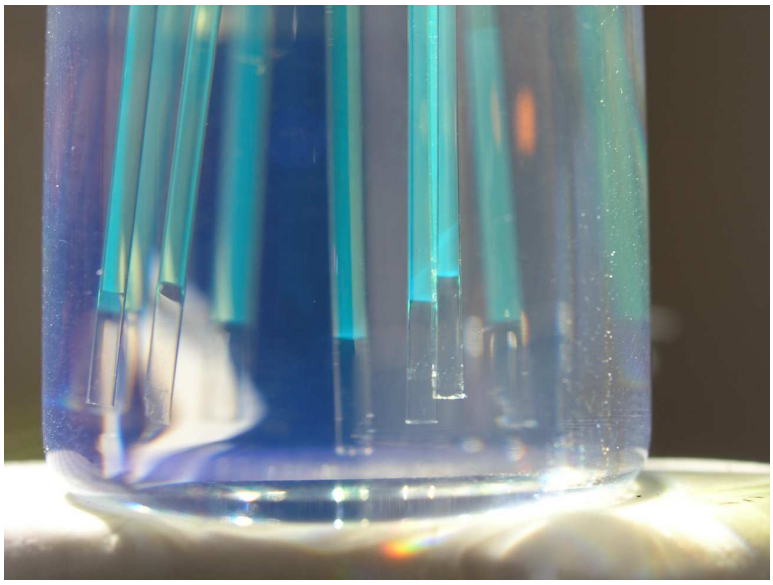
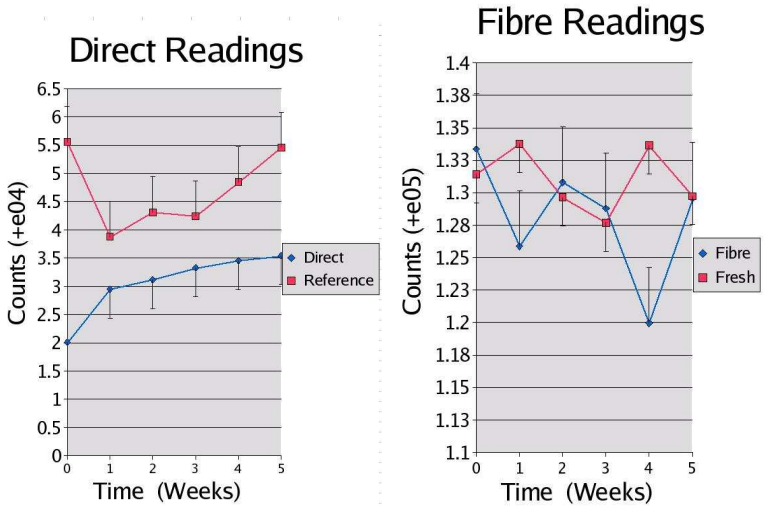


Figure 3: Fibres Incubated in QuickSafe A for One Month

For an accelerated aging test of the fibres, two more vial caps with nine wavelength shifting fibres were made and placed in identical volumes of QuickSafe A. One was kept at approximately 22℃ and the other incubated at 45℃ for one months time. Comparing the two, it was discovered that the chemicals in QuickSafe A dissolve the polystyene core and possibly the inner acrylic coating of the fibres, while leaving the outermost Teflon layer intact [Fig:3]. The incubation had accelerated the process in a manner consistent with the known aging rate of the fibres of double the effect for every 7° above room temperature.

3.4 Aging Test Results



(a) Direct Reading Results (b) Fibre Reading Results

Figure 4: Aging Study

Figure 4, which plots the average number of events recorded in three five minute trials versus the time elapsed in weeks, shows a significant, steady increase for both samples after the first week. In figure 4(a), "Direct" is the direct reading of the scintillator which has been exposed to WLS fibres, and "Reference" is the direct reading of the reference scintillator. Similarly in figure 4(b), "Fibre" means a fibre reading of the sample exposed to WLS fibres and "Fresh" is the aged fibres in a fresh vial of unused liquid scintil-

lator. It is unknown what caused this increase in efficiency. For the fibre readings the count rate remains fairly constant throughout the test. While there may be a slight downward trend, it wouldn't be unexpected. At first glance this would suggest that the performance of the fibres remains relatively constant over a period of time, however, the increase in the count rate of the scintillator alone is contradictory. It would seem that the fibres are losing efficiency as the scintillator gains, causing the fibre readings to appear constant.

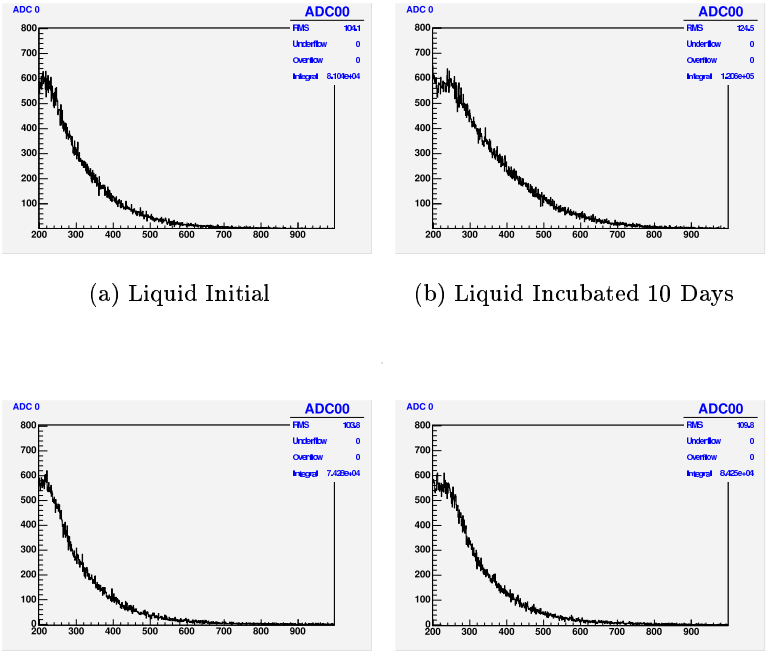
When it was discovered that the fibres were actually dissolving in the scintillator, it seemed reasonable that the extra wavelength shifting chemicals dissolved in the scintillator would explain the increase in efficiency as the fibre performance suffered but this does not explain the efficiency increase seen with the reference sample that remained untouched by fibres and shows an even larger increase.

3.5 Current and Ongoing Research

In an attempt to protect the polystyrene core from the QuickSafe A, we evaporated a thin film of aluminum on to the exposed ends of our fibres. The aluminum was meant to keep the QuickSafe A from coming in contact with the polystyrene, therefore preventing the dissolving of the fibre but this method was unsuccessful as the aluminum ends just fell off the fibres as soon as they were immersed in the scintillator.

It was thought that perhaps an argument for embedding the scintillator into a gel would be that it may slow the rate at which the fibres are dissolving as once the chemicals in contact with the fibre have done damage, it will be difficult for more of the scintillator to migrate to the fibres. The rate of deterioration may drop off after a period of time. To test this hypothesis, two sets of three wavelength shifting fibres were constructed. One set was placed in a liquid solution of 19% QuickSafe A, 9.5% Triton X-100/PPO/POPOP and 71.5%water, the other in a Carbopol EZ-3 gel with identical QuickSafe A, water and Triton X-100 concentrations. Initial readings were done with the Co-60 source and the vials and fibres were incubated for ten days' time.

No noticeable difference is seen at this point [Fig:5], the fibres will continue be incubated. It will take a much longer period of time to be able to tell if there is any significant difference between the two samples.



(a) Liquid Initial

(b) Liquid Incubated 10 Days

(c) Gel Initial

(d) Gel Incubated 10 Days

Figure 5: Effect of Phase on Fibre Deterioration Rate

4 Beam Tests

We are able to do tests using a muon beam from the cyclotron as well as the Cobalt-60 gamma source. Using the beam allows us to see an entire peak instead of just one side of a peak, making comparisons between samples more straightforward. The energy deposited in the scintillator by a high energy muon beam is much more similar to what would be experienced in the real T2K experiment than by using a gamma source. The beam is tuned to select muons of momentum 120MeV/c. A plastic scintillator (1.5cm x 1.5cm x 0.3cm) is positioned in the beam with another plastic scintillator (7.6cm x 7.6cm x 1.3cm) 4.4 metres downstream. Coincidence events are recorded and our apparatus with the test scintillator can be placed directly in between the two.

5 Biological Inhibitors

A problem arose when aqueous samples that had been prepared started to show signs of mold. It will likely be necessary to add some amount of biological inhibitor to the liquid or gel that is to be used in the near detector.

Five different biological inhibitors, all needing under 1% by weight to be effective, were purchased: Germaben II, Germaben II E, Liquipar Optima, Phenonip and Germall Plus [A.7,8]. Six identical gel mixtures were made with Carbopol EZ-3 containing 19% QuickSafe A, 9.5% Triton X-100/PPO/POPOP and water. In the process of making the gels, one biological inhibitor was added to each, leaving one as a reference. All six were duplicated without Carbopol EZ-3. The ideal biological inhibitor to use if the detector contains gel may be different than the one chosen for use in a liquid detector.

It seems none of the inhibitors decreased the light yield of the liquid phase scintillators. Liquipar Optima showed the best results in the beam test [Fig:6] and is the clearest of all the gels when kept below 24°C, otherwise it clouds over. Mixtures with Liquipar Optima also remain clear when cooled as low as 6°C while most others cloud over. Mixtures with Phenonip also remained relatively clear when cooled. All other mixtures cloud over when heated or cooled significantly.

One of the biological inhibitors, Germall Plus, was not tested in the beam as part of a gel because it caused the gel to separate into two phases and would unsuitable for use in the detector. The gel tests were less successful than the liquid tests; it seems that adding either biological inhibitor or Carbopol EZ-3 to a QuickSafe A mixture will not effect the efficiency but adding both at the same time causes a decrease in light yield of about 15% [Fig:7].

6 Conclusions

6.1 Discussion

TRIUMF is making progress towards a final design for the Near Detector. While the phase of the scintillator has not been decided, the number of candidate materials has been narrowed down. As of this point, the scintillator will be QuickSafe A, and the light yield will be read out by one millimetre, polystyrene wavelength shifting fibres. Regardless of the phase, Liquipar Optima seems the best choice for a biological inhibitor. If a gel is to be used, Carbopol EZ-3 is the most promising gelling agent of those tested to

date.

Increasing the water concentration will also effect the way the materials in the detector age. The fibres will not be dissolved as quickly since the scintillator will be diluted, but the light yield will not be as high. The longer the fibres, the more light lost by attenuation. Prototype detectors of increasing length will help determine the attenuation length of the fibres.

It has been verified that QuickSafe A dissolves the polystyrene core of the fibres but there are many possible solutions to the problem and it is still feasible that we can use these materials together to form a functional, stable detector that will endure a decade of use.

6.2 Recommendations

Even though the aluminized fibres did not work, there are still options available to protect the fibres. By contacting the manufacturer, we may be able to get fibres that have a thicker than usual coat of teflon, which would provide extra protection for the polystyrene core. Also, the cut ends of the fibre where the QuickSafe A was able to contact the polystyrene will not be exposed in the actual detector, so as long as there are no flaws in the teflon coating the scintillator should not have to come in contact with the core at all.

More aging studies should be done to determine the cause for the observed increase in scintillator efficiency as well as the effect of an increased water concentration. Building the prototype detectors will give us a better idea of the attenuation length of the fibres as well as the practical efficiency and stability of our test scintillator mixtures.

A List of References and Suppliers

A.1 Quicksafe A Liquid Scintillator

Manufacturer:
Zinsser Analytic (UK)
Howarth Road
Maidenhead, Berks. SL6 1AP, UK
Tel: +44(1628)773202
(chemist: Robert Huggett r.huggett@zinsser-analytic.com)
www.zinsser-analytic.com

North American supplier:
Zinsser North America, Inc.
www.zinsserna.com
714-379-8900
(contact: Jim Schools jimschools@zinsserna.com)

A.2 Water Crystals (polyacrylate)

WaterCrystals.Com
Tandem Marketing
4345 Beverly Street, Suite G
Colorado Springs CO 80918-5916, USA
tel. 719-599-1741 fax 719-599-3944
www.watercrystals.com

A.3 Carbopol EZ-3

Manufacturer:
Noveon, Inc.
9911 Brecksville Road,
Cleveland, OH 44141-3247, USA
1-800-379-5389
www.noveoninc.com, www.carbopol.com

Canadian supplier:
L.V. Lomas
Delta, BC
1-800-668-1221

604-521-7779
www.lvlomas.com

A.4 Aculyn

Manufacturer:
Rohm and Haas
100 Independence Mall West
Philedelphia, PA 19106, USA
1-800-922-8596
www.rhpersonalcare.com/aculyn.html

Canadian supplier:
Univar
9800 Van Horne Way
Richmond, BC V6X 1W5
604-273-1441
www.univarcanada.com

A.5 RapidThix, Stabileze QM

International Specialty Products
www.ispcorp.com/products/hairskin/content/haircare/brochure

Canadian supplier:
Amisol
3425 Laird Road, Unit #5
Mississauga, Ontario L5L 5R8
Tel: (905) 608-8766
Fax: (905) 608-8755
e-mail sales@amisol.com

A.6 Klucel, Natrosol

Hercules Inc.
Aqualon Division
1313 North Market St.
Wilmington, DE 19894-0001, USA
302-594-5000
www.aqualon.com

Canadian supplier:
St. Lawrence Chemicals
604-507-0761
www.stlawrencechem.com

A.7 Germaben, Liquapar Optima, Phenonip

The Chemistry Store.com
1-800-224-1430
www.chemistrystore.com/preservatives.htm

A.8 Germall Plus

Voyageur Soap & Candle Co.
Unit 15 - 19257 Enterprise Way
Surrey, BC, Canada V3S 6J8
(604)530-8979, 1-800-758-7773 (orders)
www.voyageursoapandcandle.com

B Procedure - Gel Samples for Beam Test

B.1 Carbopol EZ-3

To make the sample of Carbopol EZ-3 used in the beam test, 0.12g of Carbopol EZ-3 powder was dissolved in 15ml of water. A second mixture was made consisting of 4 ml of QuickSafe A, 2ml of Triton X-100/PPO/POPOP and 0.125ml of a sodium hydroxide stock solution (1.8% NaOH by weight). The two phases are mixed together by adding 1.5ml of the Carbopol EZ-3/water phase and then 0.6ml of the QSA/Triton X-100/NaOH phase repeatedly until both mixtures are gone. A propeller-like stirring tool is carefully used to mix the two phases together, minimizing the number of air bubbles stirred into the gel.

B.2 Stabileze QM

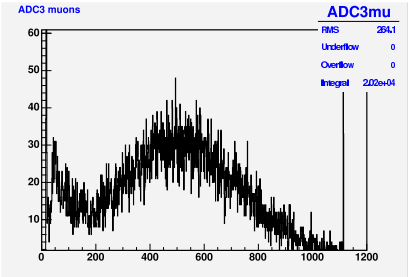
A Stabileze QM stock solution was made by dissolving 2 grams of the powder in 100ml of water and heating to 70°C for 45 minutes. A mixture of 8ml water, 2ml Triton X-100/PPO/POPOP and 4 drops of a more concentrated NaOH solution (18% NaOH by weight) was added to 4ml of the Stabileze stock solution to form the final gel used in the beam test. The mixture was carefully stirred.

B.3 RapiThix A-60

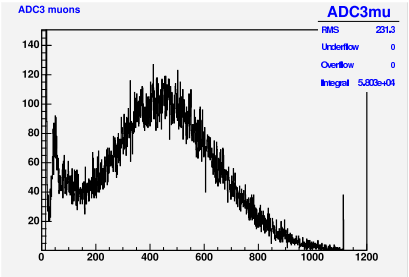
0.2ml of the RapiThix A-60 liquid was added to a mixture of 4ml QuickSafe A, 2ml Triton X-100/PPO/POPOP and 15ml of water and stirred.

B.4 Aculyn 22

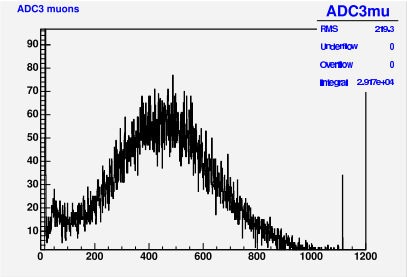
For Aculyn 22, a mixture of 4ml QuickSafe A, 2ml Triton X-100/PPO/POPOP, 16ml water and 5 drops of NaOH (18% by weight) was made and 0.8ml of Aculyn 22 was added. The mixture was stirred. Several attempts to recreate this sample failed with the 18% NaOH stock solution. The pH is more easily controlled when made with a 1.8% stock solution.



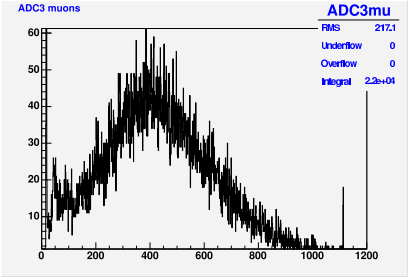
(a) QuickSafe A, Carbopol, Water



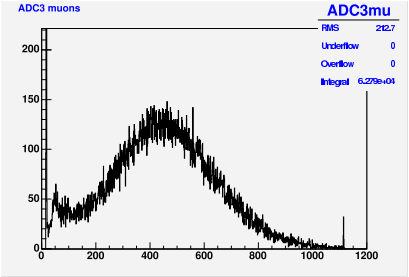
(b) QuickSafe A, Carbopol, Water and Germaben II



(c) QuickSafe A, Carbopol, Water and Germaben II E

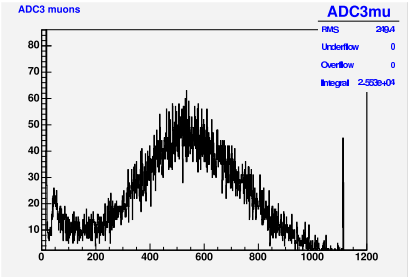


(d) QuickSafe A, Carbopol, Water and Liquipar Optima

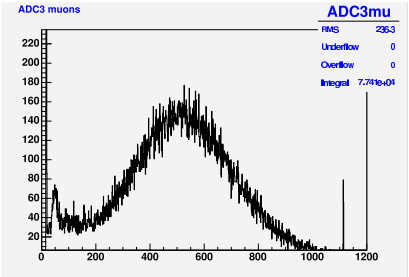


(e) QuickSafe A, Carbopol, Water and Phenonip

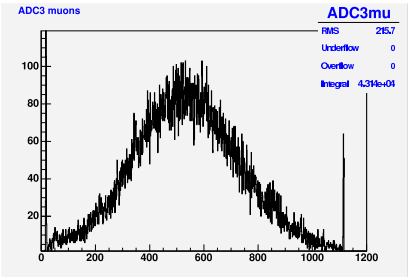
Figure 6: Biological Inhibitors with QuickSafe A Mixture - Gel Form



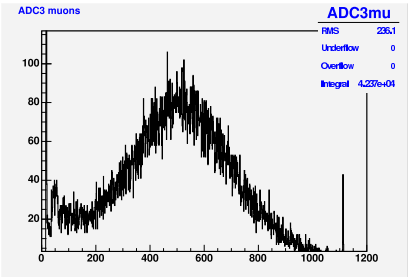
(a) QuickSafe A and Water



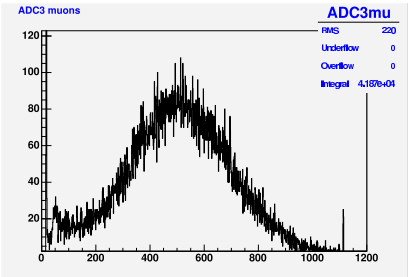
(b) QuickSafe A, Water and Germaben II



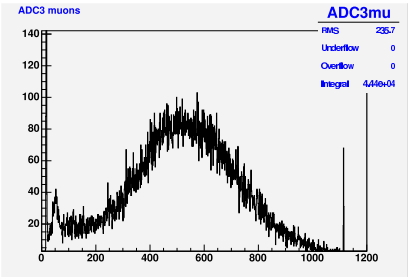
(c) QuickSafe A, Water and Germaben II E



(d) QuickSafe A, Water and Liquipar Optima



(e) QuickSafe A, Water and Phenonip



(f) QuickSafe A, Water and Germall Plus

Figure 7: Biological Inhibitors with QuickSafe A Mixture - Liquid Form