Water-based Liquid Scintillator Purification

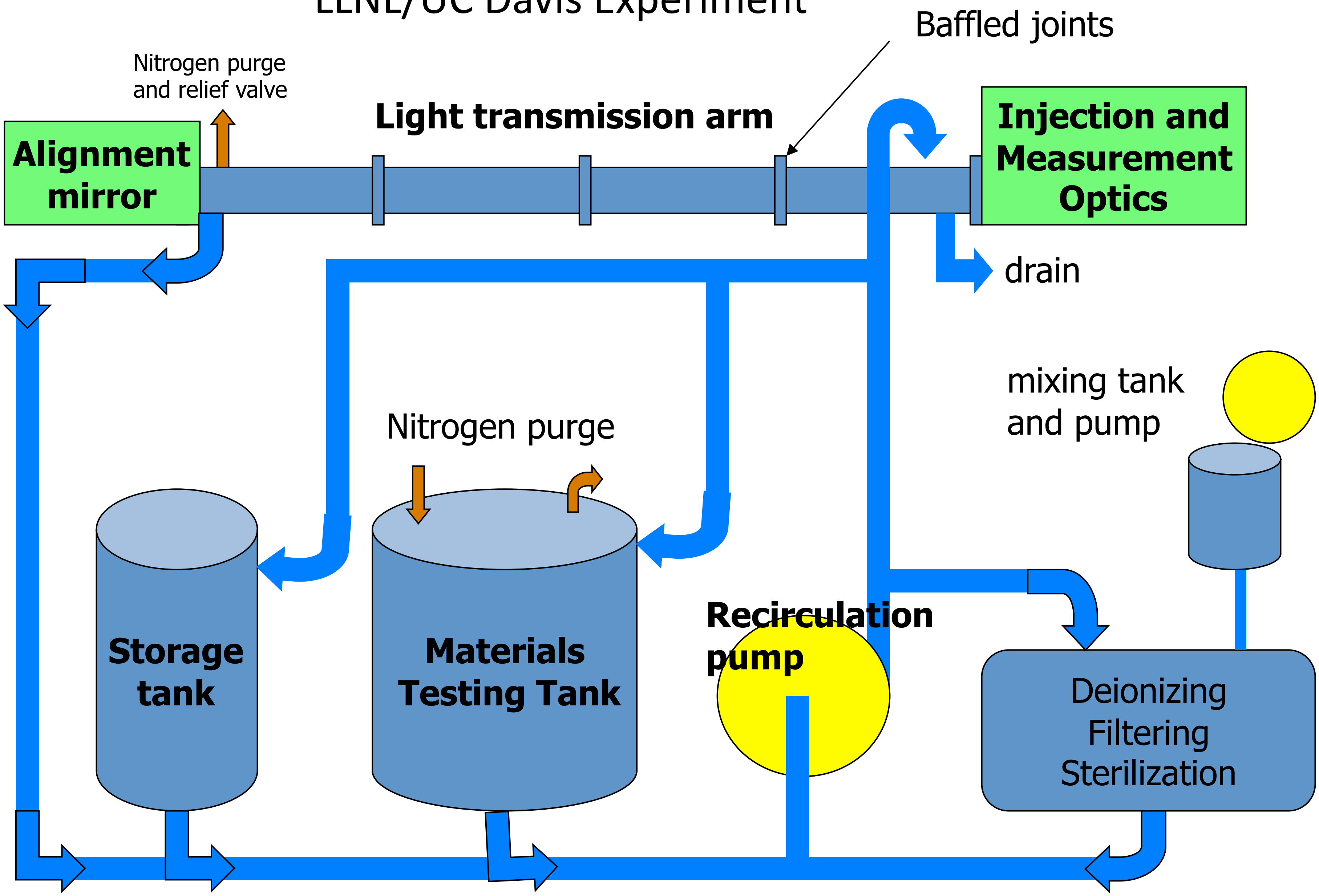
Robert Svoboda, FroST - Topical Workshop for THEIA

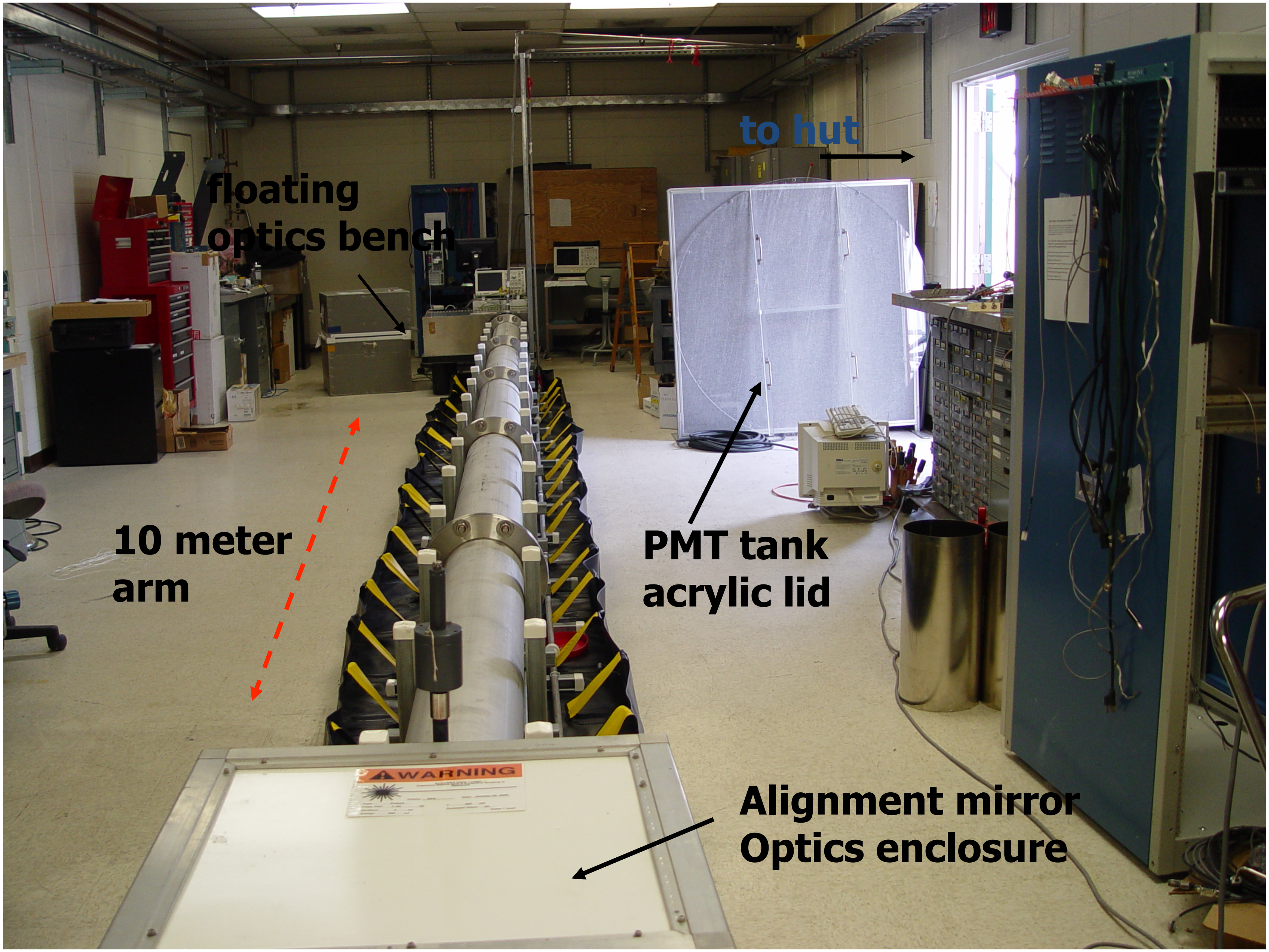
Why does good water go bad?

- Super-Kamioande, like other water Cherenkov detectors before it, requires nearly continuous recirculation to maintain optical transparency. **Why?**
- Tests at Lawrence Livermore National Laboratory* have revealed that the interaction of *pure water with stainless steel* is likely the reason for Super-Kamiokande

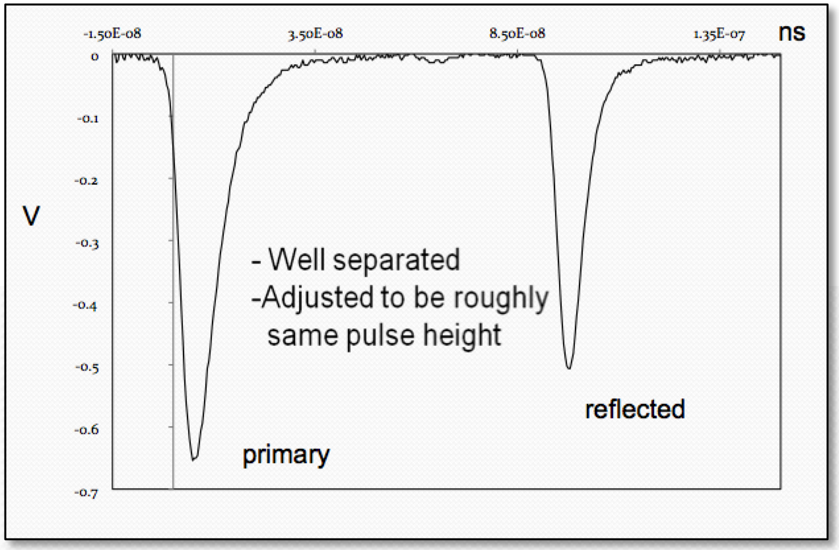
* W. Coleman, A. Bernstein, S. Dazeley, R. Svoboda, NIM A **595** 339 (2008)

LLNL/UC Davis Experiment

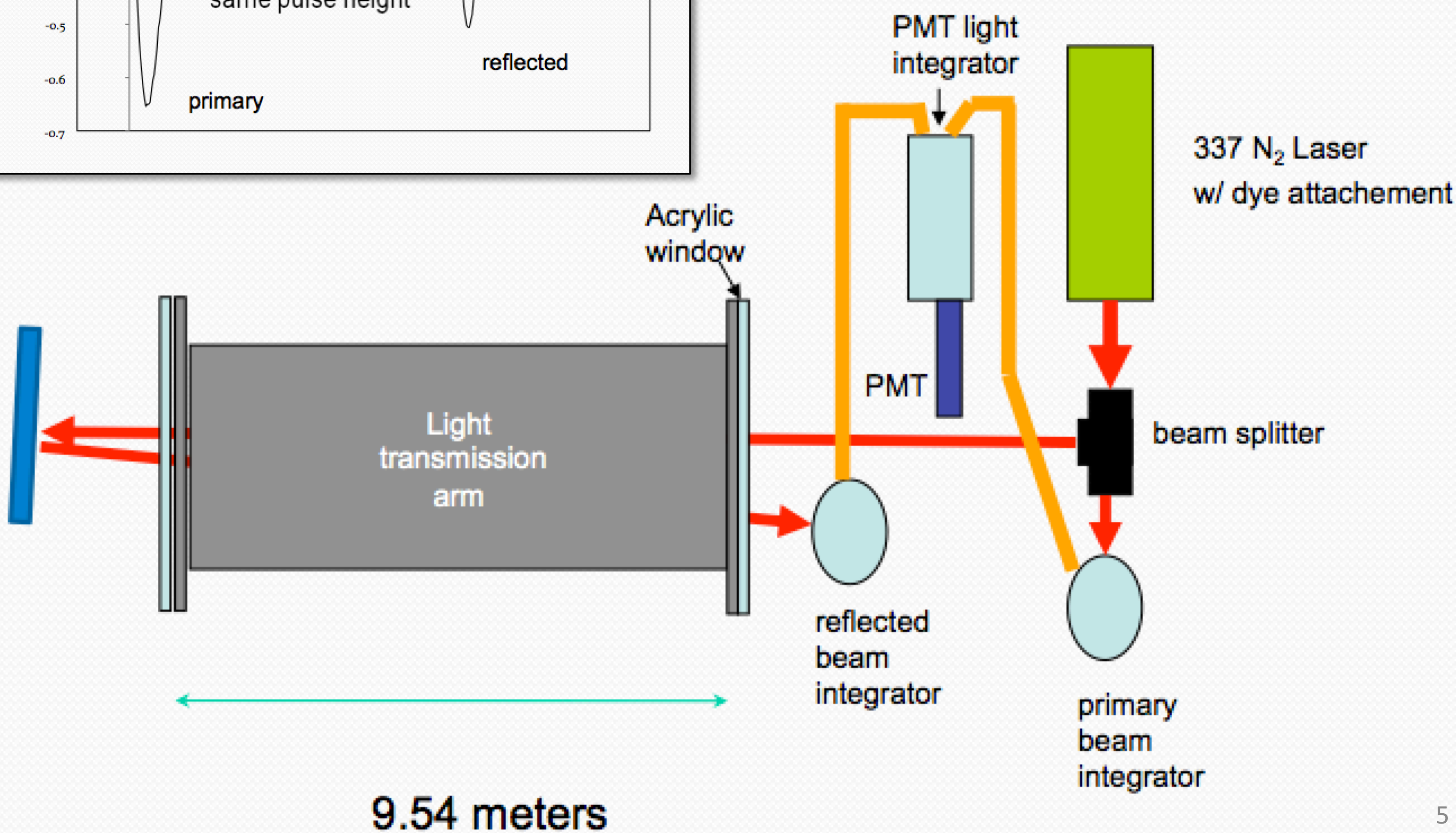




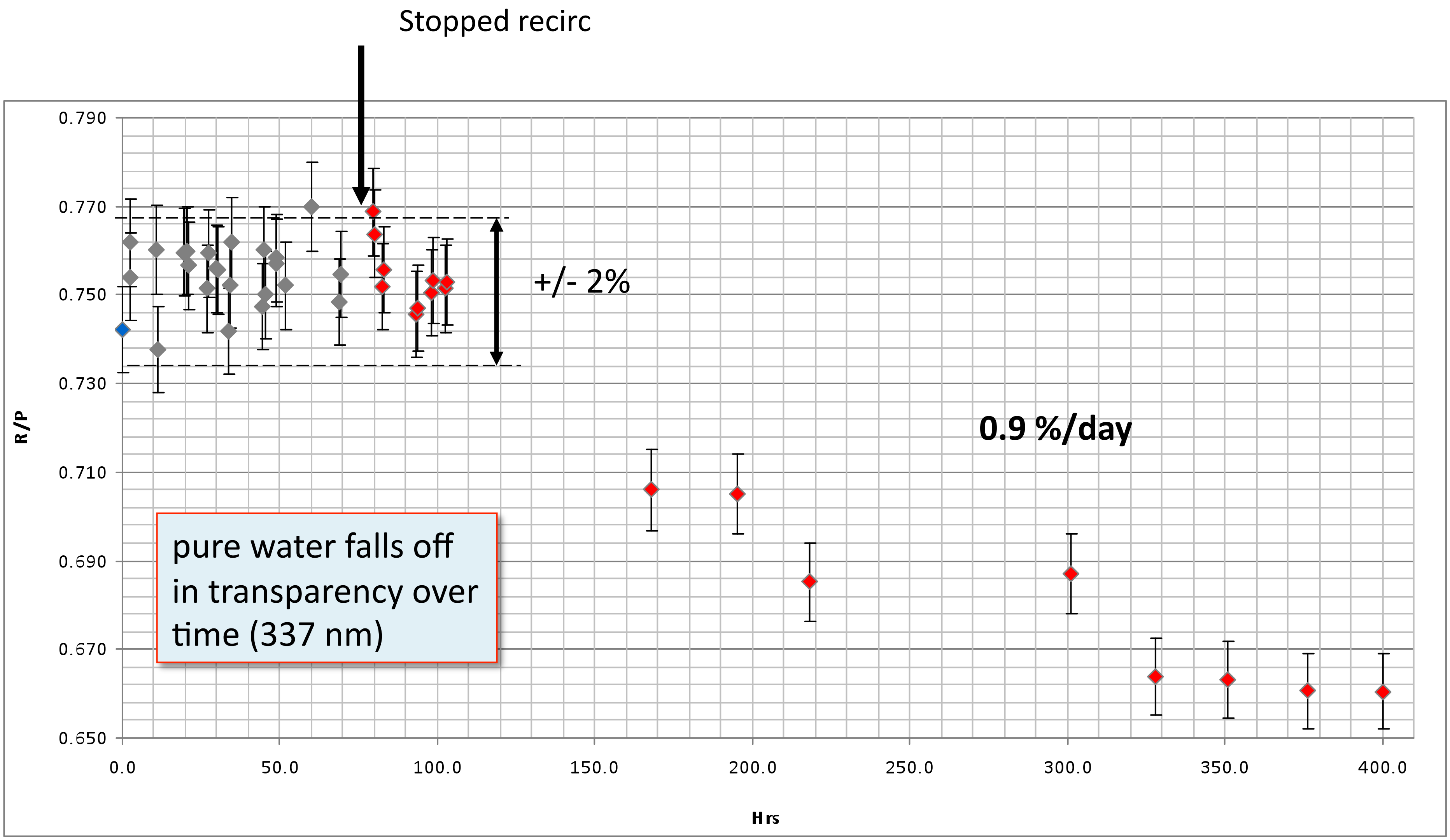
to hut
floating optics bench
10 meter arm
PMT tank acrylic lid
WARNING
Alignment mirror Optics enclosure



The ratio of outgoing and return pulse (ρ) changes linearly with transparency



Pure water lost transparency in the UV even in a sterile low oxygen sealed environment. This effect was estimated to be large enough to explain the SK experience.



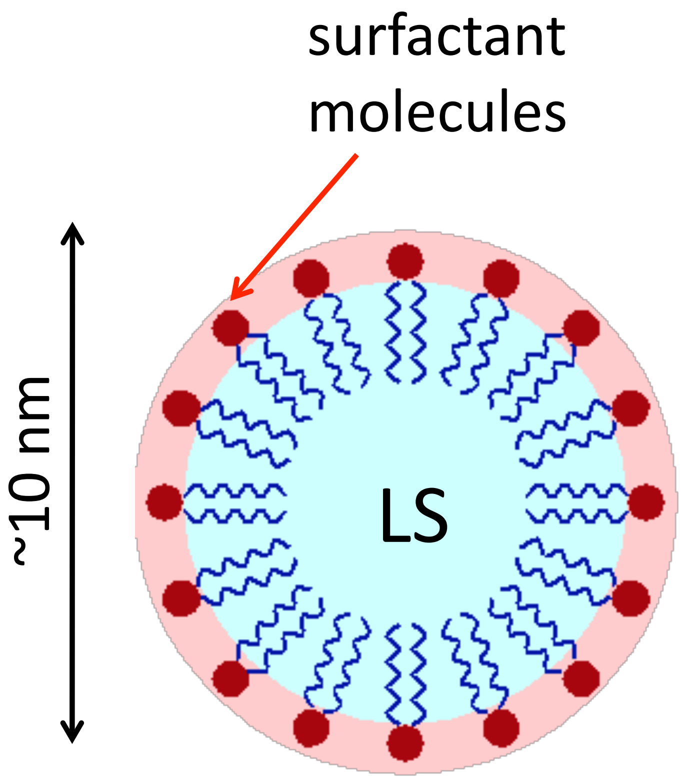
Adding ppb levels of $FeCl_3$ reproduces this effect

Table 4.7: The change in ρ resulting from the addition of $FeCl_3$ to pure water.

pure water value	14 ppb $FeCl_3$ in water	28 ppb $FeCl_3$ in water
0.901 ± 0.018	0.355 ± 0.018	0.156 ± 0.008

Cannot use EGADS system on WbLS as the molecules of the organic component are non-polar and do not pass through.

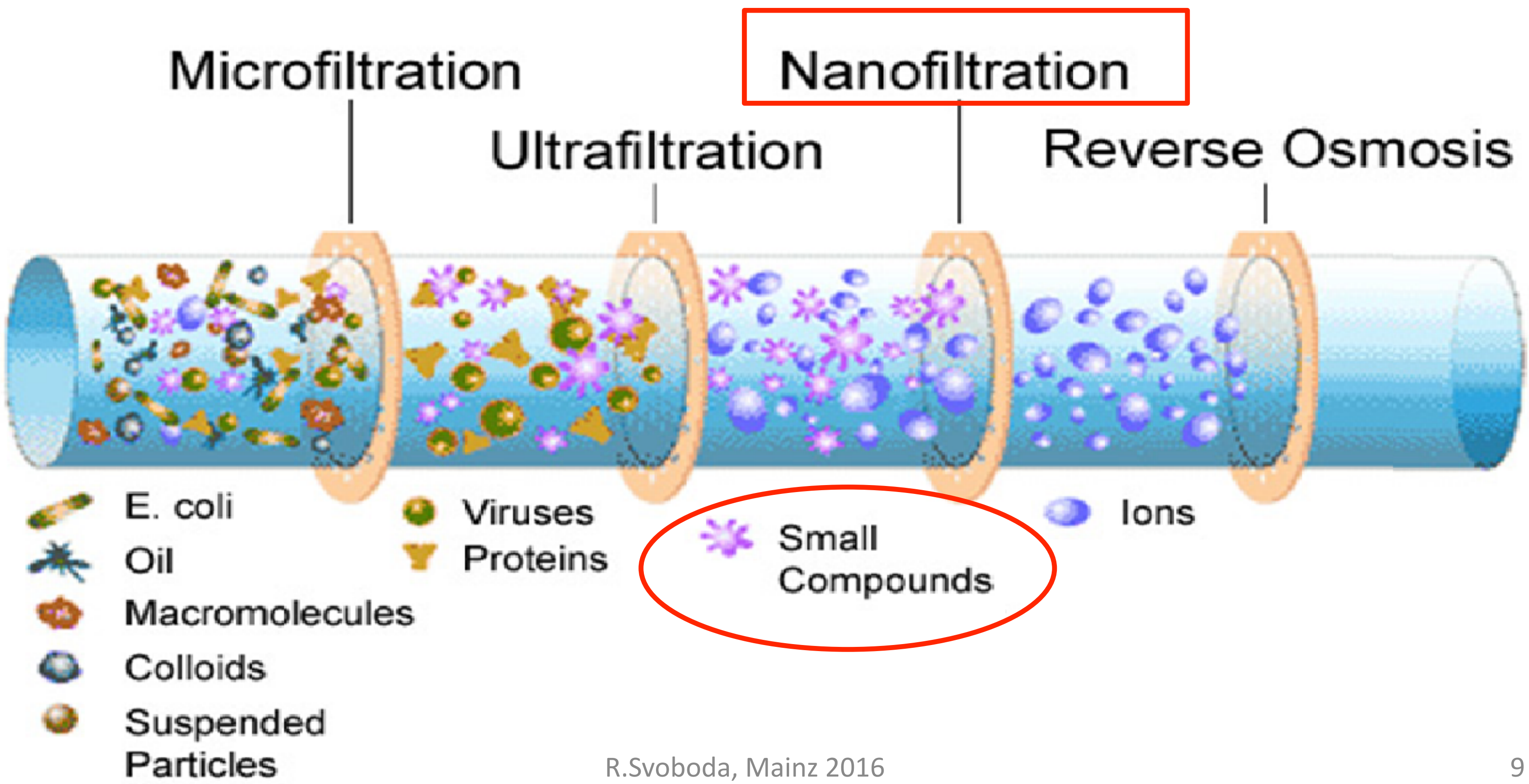
Micelle sequestering of LS in water



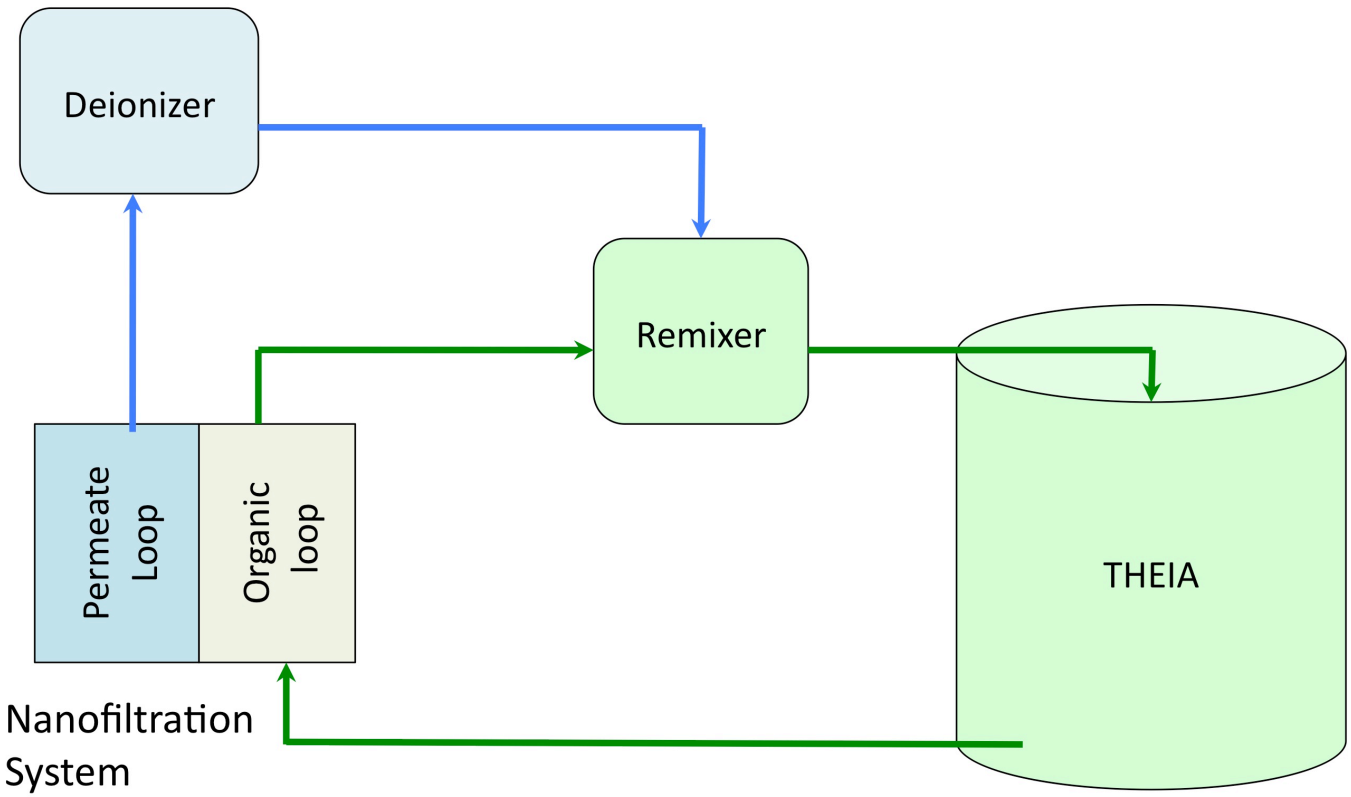
Liquid Scintillator (LS) forms small (~10 nm scale) droplets called *micelles* in water that are stabilized by surfactant molecules with a hydrophilic head and hydrophobic tail. Micelles form under controlled chemical conditions.

Do not want to disrupt the micelles during purification else light yield may be significantly affected.

Nanofiltration is used by the food industry and by industries concerned with environmental pollution caused by trace amounts of oil in water



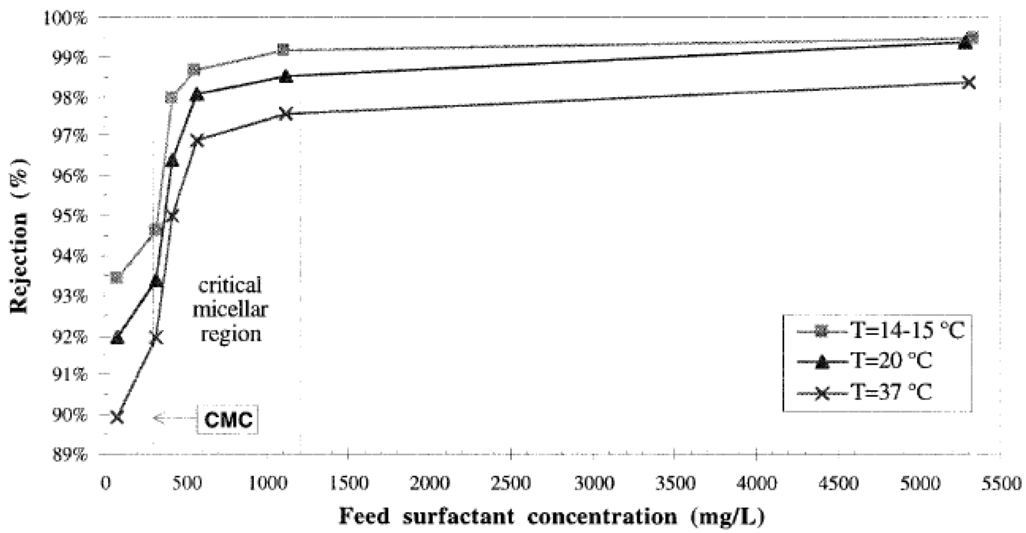
Using NF one could try and separate the organic and water stream, purify the water stream, then remix.

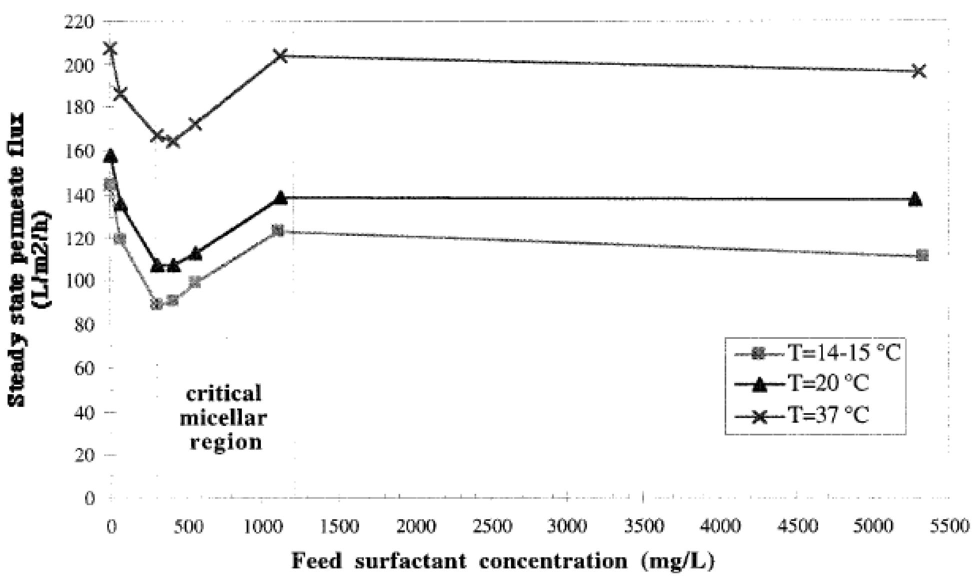


THEIA recirculation concept

There are many considerations

- Identification of appropriate Molecular Weight CutOff (MWCO) hydrophilic materials to use for filters to avoid surface fouling and concentration saturation effects
- Optimal temperature and pressure to yield sufficient flow rate but significant rejection
- Passage of ionic contaminants through the system for later removal by deionization
- Micelle formation and disruption effects





Feed flow rates and rejection depend on temperature and flow rates. We want high flow rate but also high rejection of organics

Separation of an Anionic Surfactant by Nanofiltration

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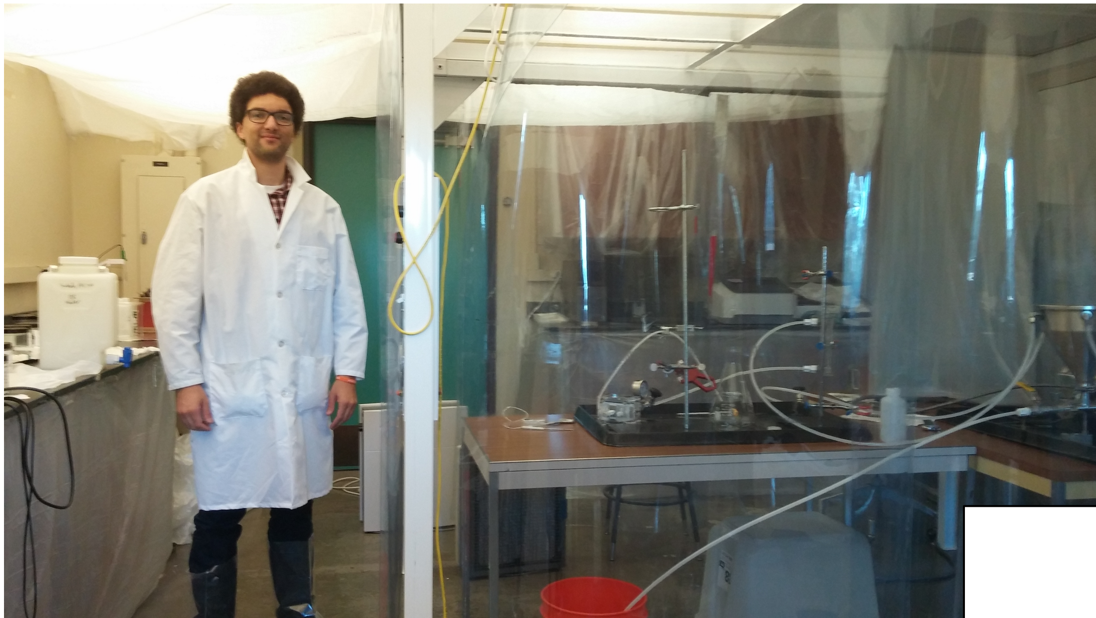
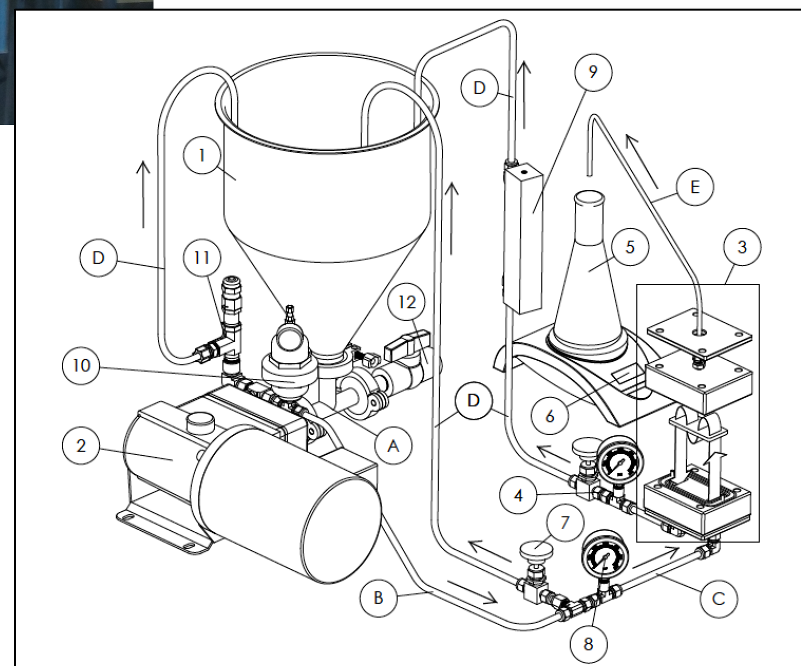
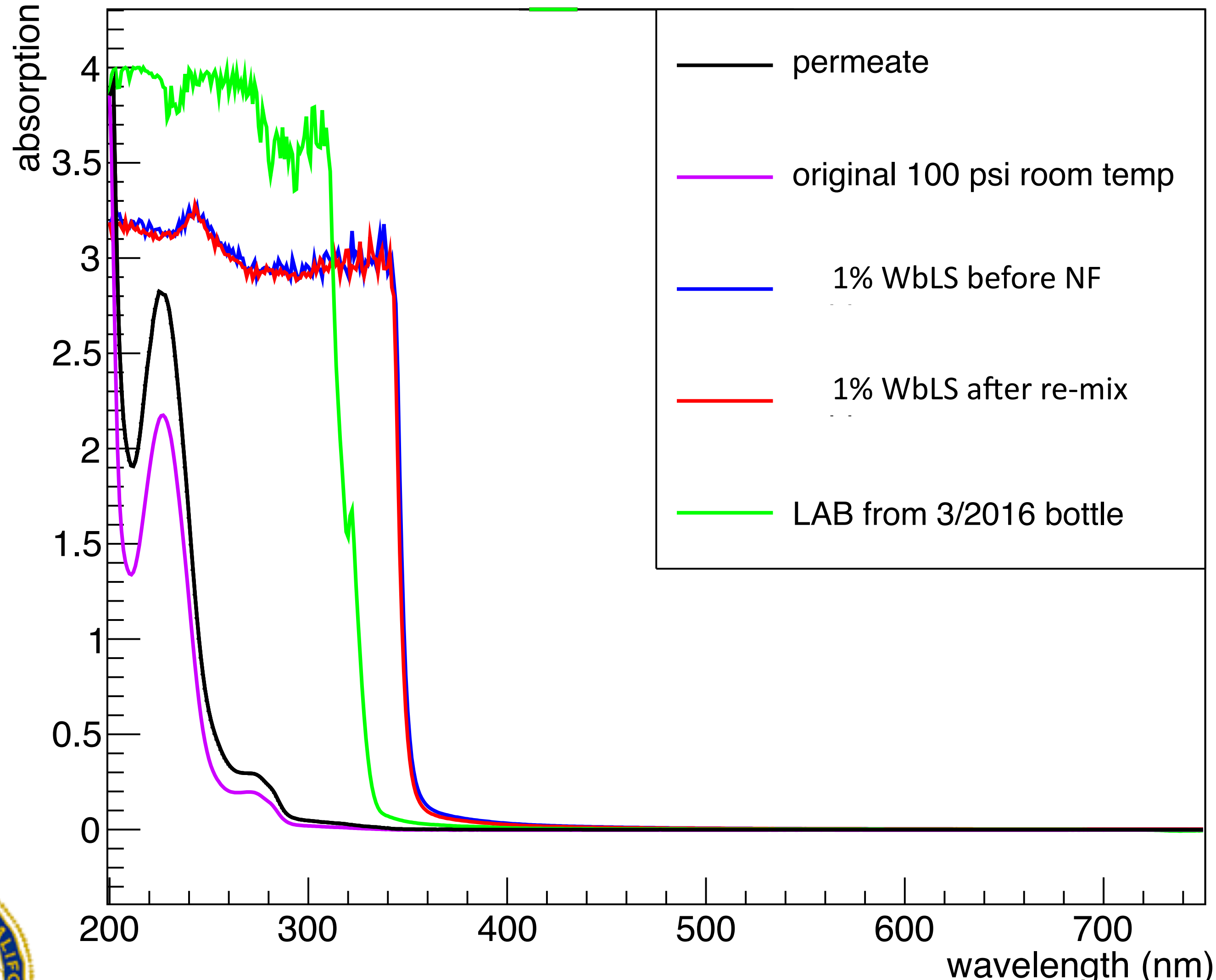


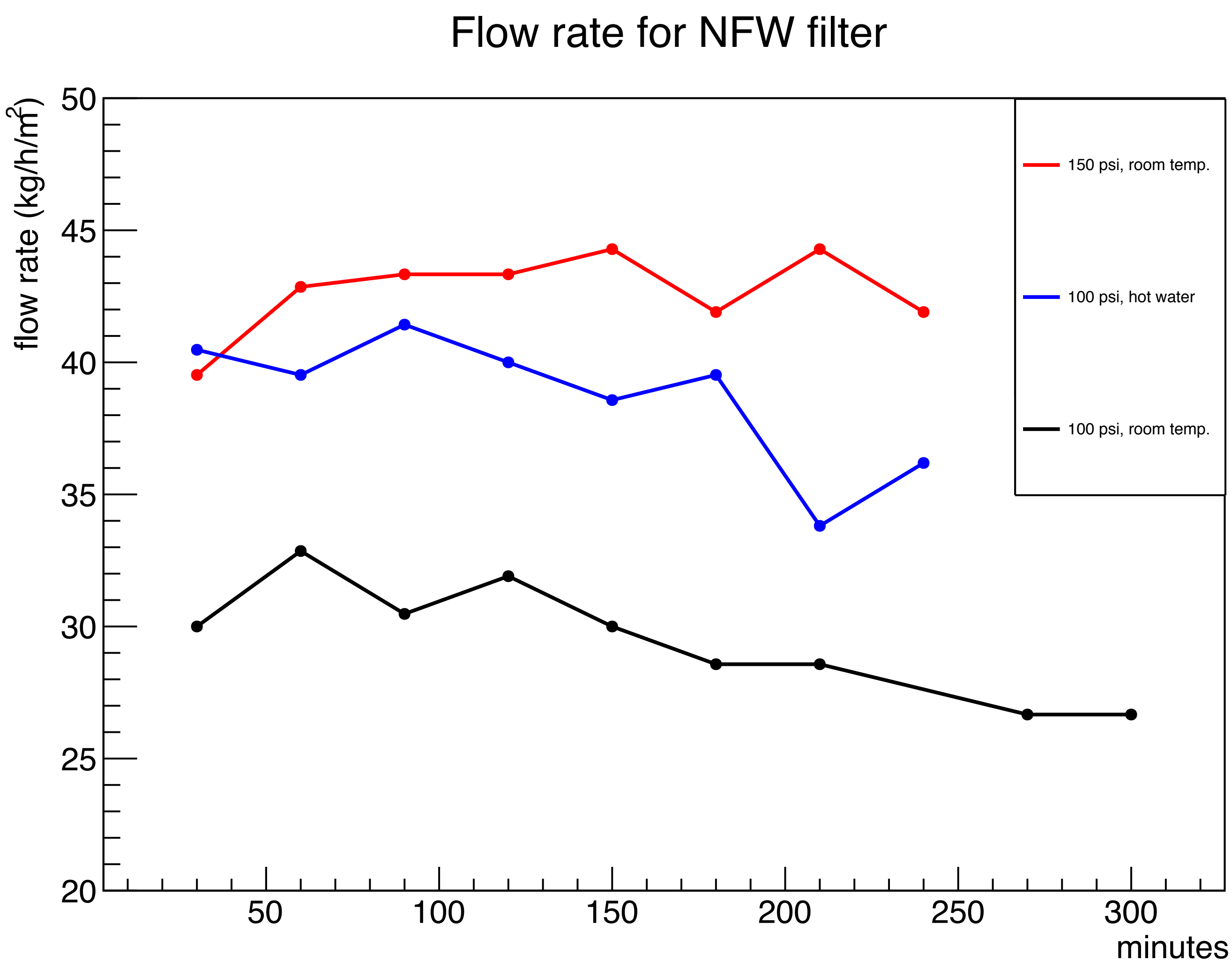
UC Davis Nanofiltration Development Laboratory

Sterlitech CF042 Nanofiltration Unit Modified a for a permeate loop to overcome concentration polarization and fouling issues.



Test Results for Snyder NFW Polymide 300-500 MWCO

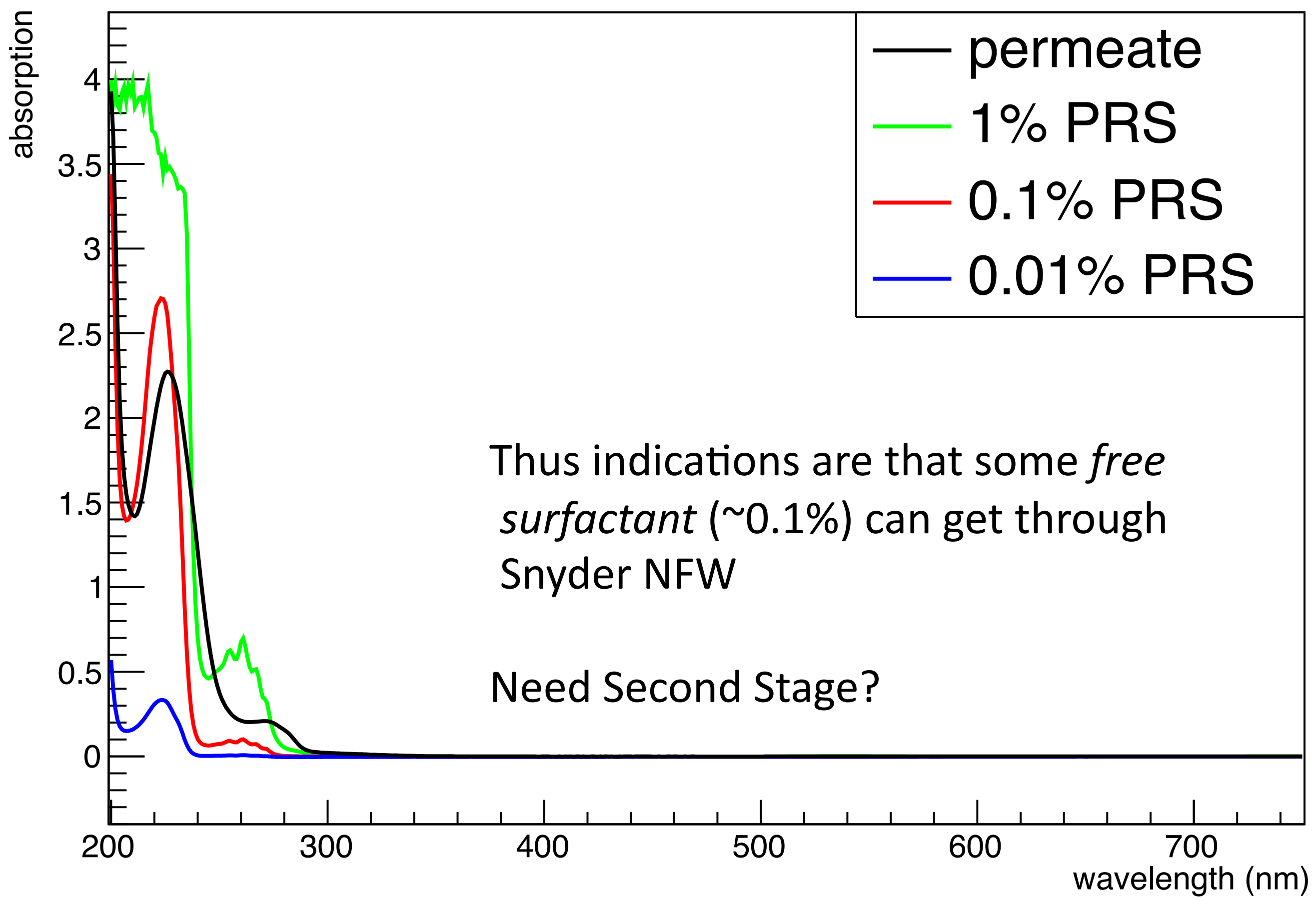




Scale up to commercially available facility would mean about 1 kton per day. **This is feasible for THEIA!**

What is making it through the NF?

PRS calibration =Linear Alkyl Sulfonate



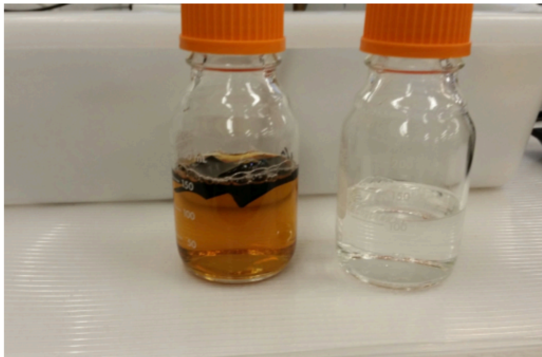
Thus indications are that some *free surfactant* (~0.1%) can get through Snyder NFW

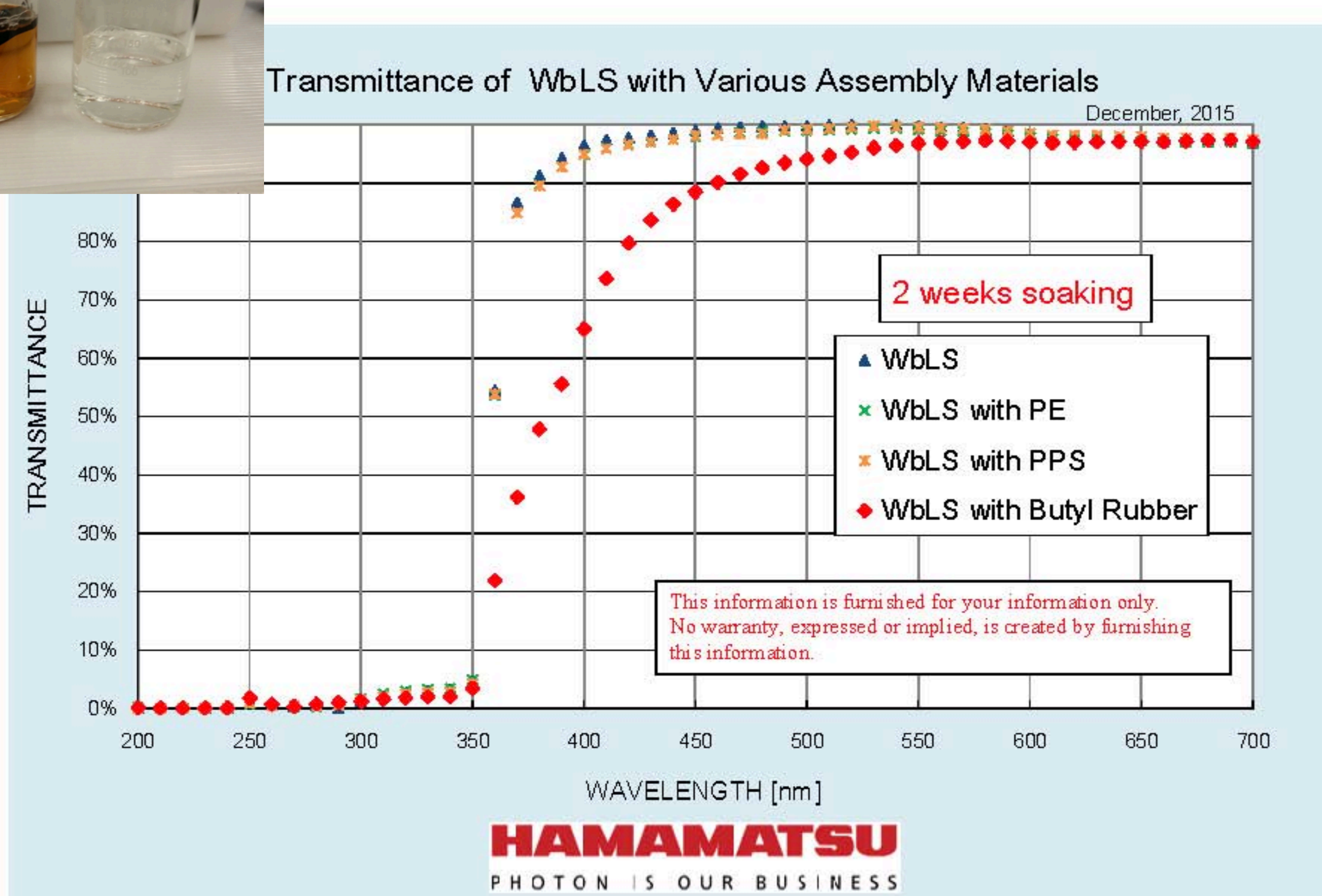
Need Second Stage?

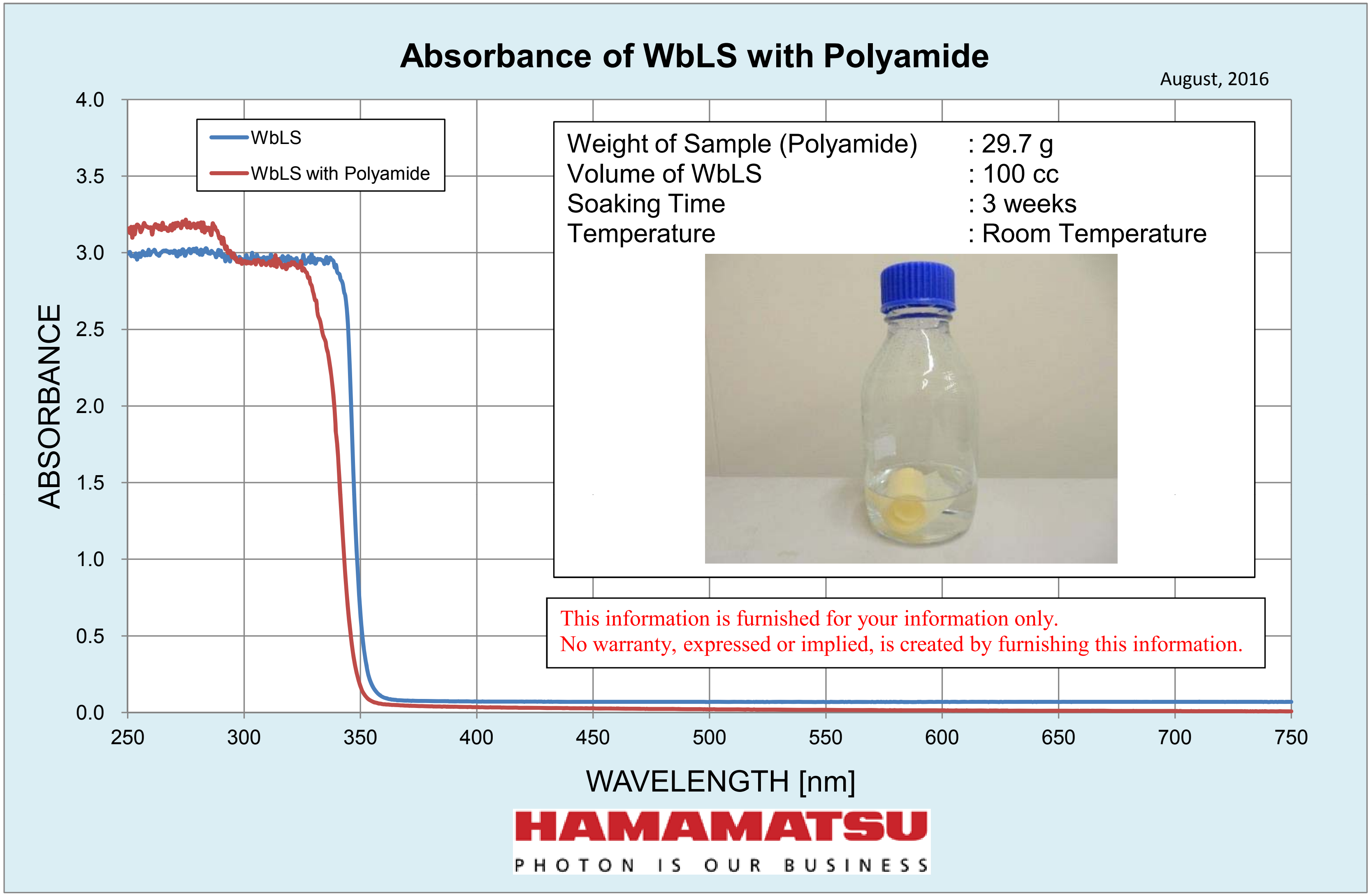
Next Steps

- Try second stage "tight" filter on permeate to remove free surfactant
- Test with ionic contaminants (E.g. iron ions) to see that they make it through both stages
- Test that light yield if not affected by this process
- Temperature and pressure optimization
- Scale up to prototype (ANNIE?)

Material Compatibility

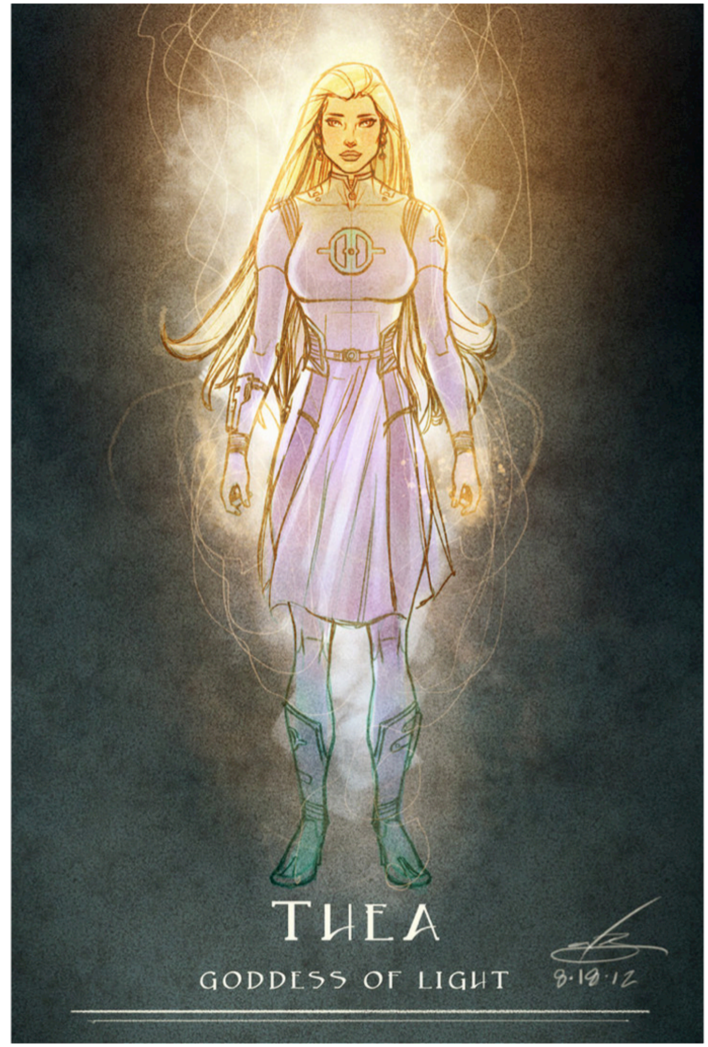





Absorbance of WbLS with Polyamide
August, 2016
WbLS
WbLS with Polyamide
Weight of Sample (Polyamide) : 29.7 g
Volume of WbLS : 100 cc
Soaking Time : 3 weeks
Temperature : Room Temperature
This information is furnished for your information only.
No warranty, expressed or implied, is created by furnishing this information.
ABSORBANCE
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
250
300
350
400
450
500
550
600
650
700
750
WAVELENGTH [nm]
HAMAMATSU
PHOTON IS OUR BUSINESS

Summary

- The active component of WbLS has been successfully separated from the water matrix using NanoFiltration (NF) techniques. Flow rates are high enough to be practical for use in THEIA
- A second stage is needed to remove free surfactant, and tests of ion removal still remain to be done
- Material compatibility studies are on-going
- A scaled up prototype may be useful to consider



Backup

Table 4.5: Estimated uncertainties associated with the measurement of ρ.

Percent Uncertainty	**Wavelength**		
	337nm	**400nm**	**420nm**
Short–Term Stability	0.6	4.4	2.0
Alignment	1.0	2.0	2.0
Long–Term Stability	1.0	2.5	2.0
Linearity	0.8	1.1	1.6
Total	**1.7 %**	**5.6 %**	**3.8 %**

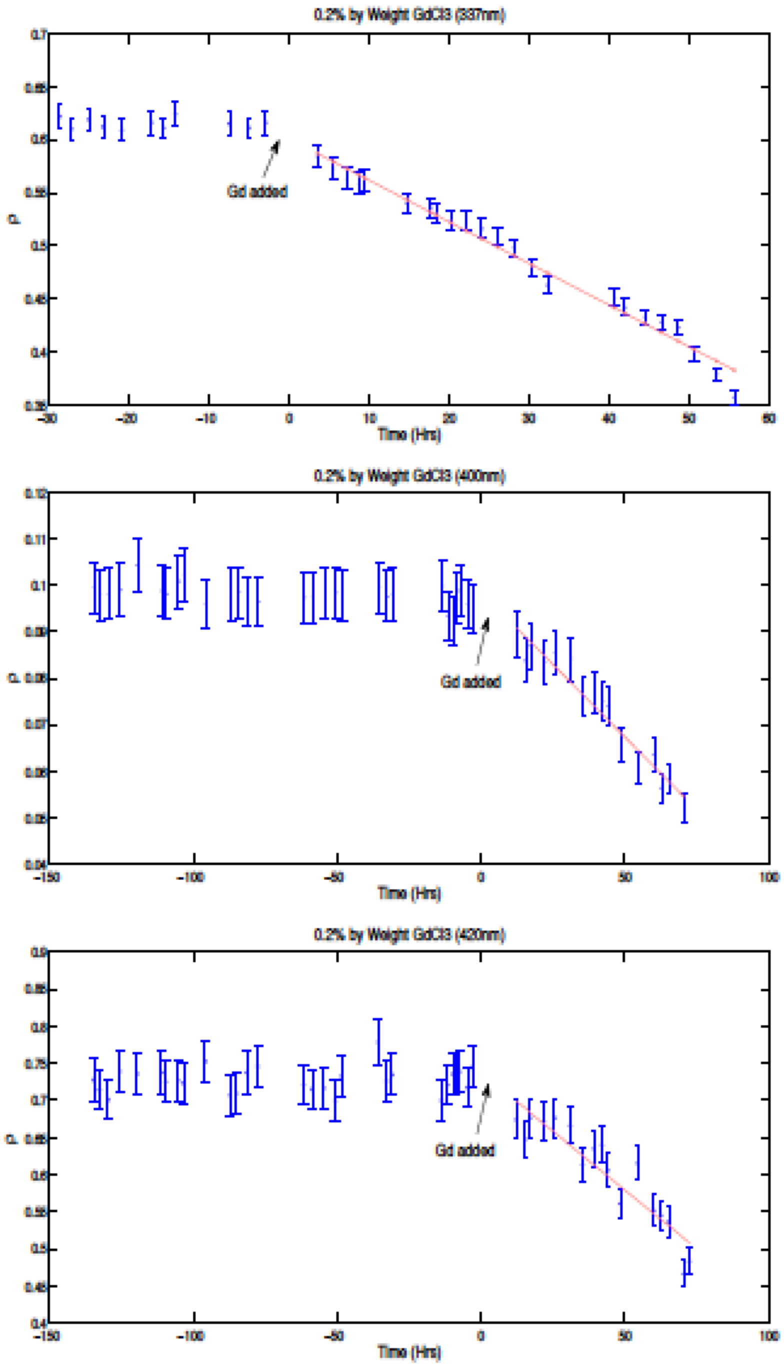
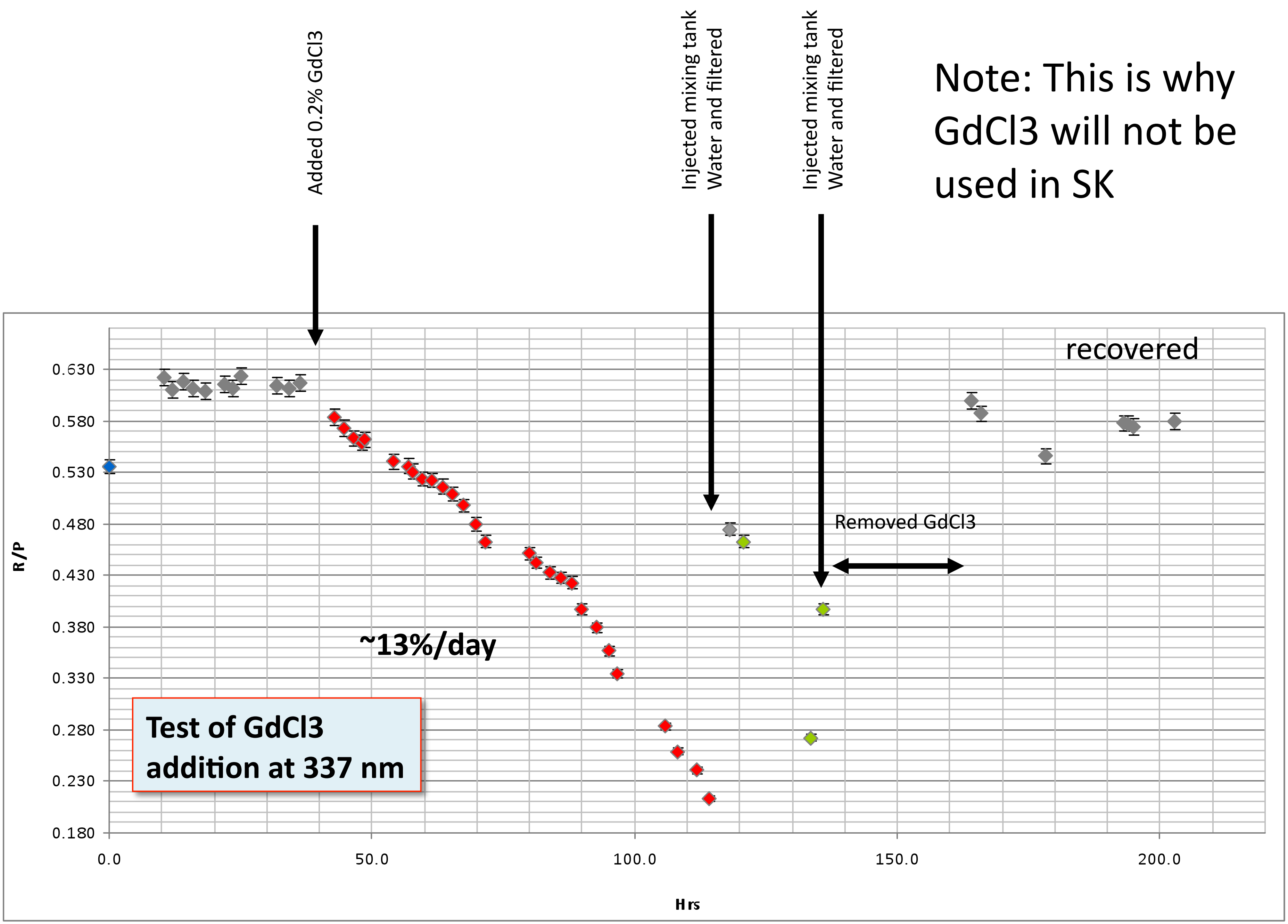


Figure 4.10: Decrease in transparency versus time resulting from addition of 0.2% $GdCl_3$ in pure water for 337 nm (a), 400 nm (b) and 420 nm (c). The red line shows the least squares best fit to the data after addition of the $GdCl_3$.


Added 0.2% GdCl3
Injected mixing tank Water and filtered
Injected mixing tank Water and filtered
Note: This is why GdCl3 will not be used in SK
recovered
Removed GdCl3
~13%/day
Test of GdCl3 addition at 337 nm
R/P
Hrs
0.630
0.580
0.530
0.480
0.430
0.380
0.330
0.280
0.230
0.180
0.0
50.0
100.0
150.0
200.0