Optimization of the Liquid Scintillator Composition

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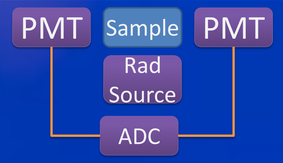
COSMIC RAYS AND PARTICLES GROUP

Motivation

- ✓ Liquid or plastic based organic scintillators are popular charged particles detection medium
- ✓ Fast, high light yield and inexpensive
- ✓ Both cost and light emission spectra are driven by types and amounts of the wavelength shifters (WLS) added
- ✓ Normally 2 are added [1]: fluor and shifter for readout using typical PMT or WLS fibers
- ✓ Each experiment does the optimization anew for their needs
- ✓ Our goal was to carry out generalized measurements to help future experiments jump-start their scintillator optimization R&D based on project results
- ✓ Currently, still work in progress. Water-based scintillator to be studied as well.

PPO concentration

Experiments with MELZ-FEU [2] PMT-115M and ^{60}Co radioactive source.



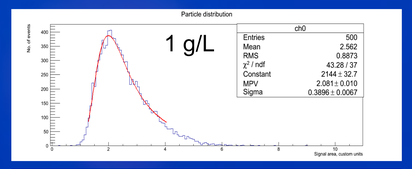
Experimental setup: 2 PMTs, PMT holder, radioactive source, test tube with liquid scintillator.

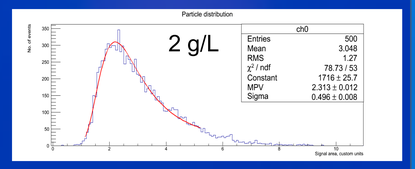
CAEN [3] DT5743 ADC was used to internally handle the double coincidence between the PMT signals.

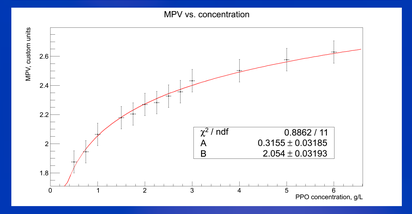
- •PC – pseudocumene (1,2,4-Trimethylbenzene)
- •PPO - 2,5-diphenyloxazole
- •MSB - 1,4-Bis(2-methylstyryl)benzene
- •POPOP - 1,4-di-(5-phenyl-2-oxazolyl)-benzene

Concentration, g/L	PPO solution added, µL
0.5	34.97
0.75	52.92
1	71.19
1.5	108.72
1.75	127.99
2	147.63
2.25	167.63
2.5	188.01
2.75	208.77
3	229.93
4	318.79
5	415.02
6	519.59

PPO result



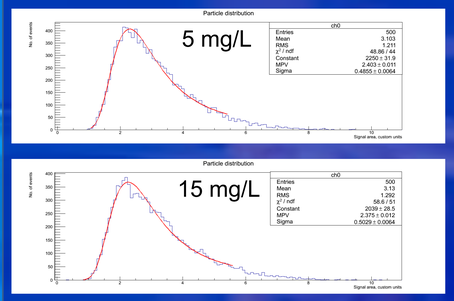




0.5 g/L is the lowest concentration with detectable signals.

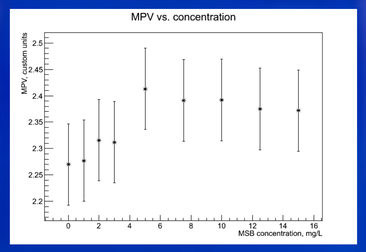
Graph of the light yield (MPV from fit) vs. PPO concentration is logarithmic, so there is no optimal concentration of PC+PPO solution, as the slope of logarithmic function decreases monotonously.
Sample of 2 g/L concentration was chosen for future tests as widely used.

PPO 2 g/L + MSB



Adding MSB to the PC+PPO sample decreases the light yield as seen by PMTs. As more is added, the less light is detected.

The reason is that PMT sensitivity is nearly similar between 380 and 410 nm. So MSB absorbs the PPO emitted light and then re-emits only part of it.

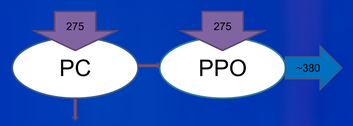


Spectrophotometer

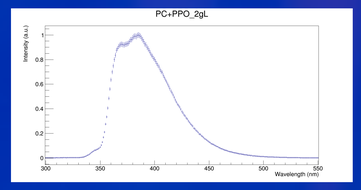
It was decided to check the sample's emission spectra difference for different concentrations of MSB and POPOP in PC+PPO+MSB and PC+PPO+POPOP samples respectively.

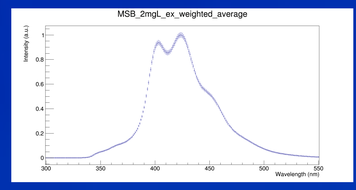
Experiments on spectroscopy were done using Agilent [4] Cary Eclipse spectrophotometer.

Samples were excited by 275 nm light and spectrophotometer read the emitted light in the range of 300-550 nm.



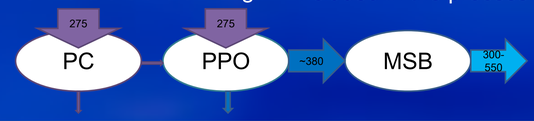
PC+PPO & PC+MSB spectra



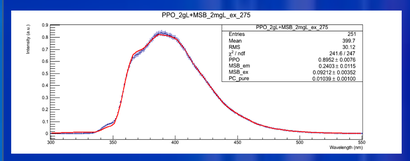


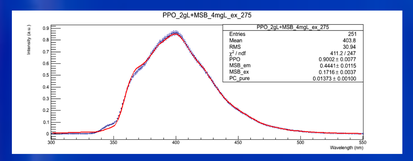
PC+PPO sample's spectrum was observed.
PPO shifts the incoming light, while PC itself has a negligible contribution.
Adding MSB furthers the shifting.

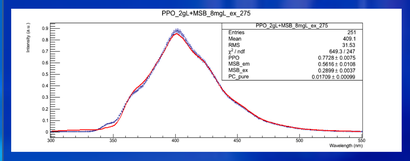
To understand the contribution of MSB, its spectrum was also recorded as exited by ~380nm light range.
No light emitted MSB exciting by 275 nm, so only contribution from PPO was included in the process.



PC+PPO _2g/L+MSB spectra







To see what happens: spectra for several different concentrations of MSB in the sample were observed. All the spectra of components were averaged and then used to make a fit of the light emitted by the sample.

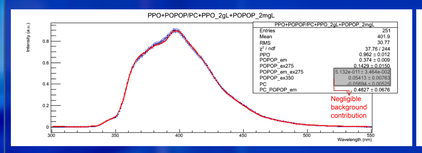
From the light absorbed by MSB, only 40%-50% of it is re-emitted. Thus total light yield reduces.

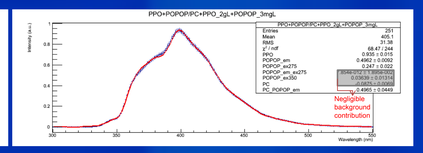
$$(A-B*[MSB\_abs])*[PPO\_em]+C*[MSB\_em]+D*[PC\_em]$$

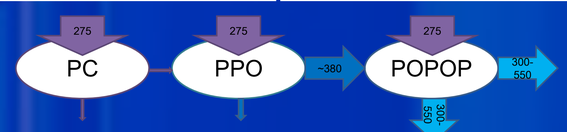
PC+PPO _2g/L+POPOP spectra

With POPOP the process is somewhat different. POPOP not only shifts light from PPO, but also absorbs and re-emits the incoming 275nm light.
Model of the sample's spectra is complicated.

The same formula as for MSB sample doesn't fit well. Even though some models do fits the obtained spectrum as presented, the work is still in progress.







Results

- ✓ PC+PPO scintillator and fluor combination was studied. Light emitted by this combo logarithmically depends on the amount of PPO added.
- ✓ PMTs used have almost linear QE in 380nm-410nm range thus MSB or POPOP addition reduced total light yield.
- ✓ PC+PPO+MSB analysis showed the contribution of each component in the sample, formula for light yield was derived.

Future plans

- ✓ Create a model for PC+PPO+POPOP scintillator light emission.
- ✓ Study water-based liquid scintillator (dissolve already obtained scintillators in water using sodium sulphonate)

REFERENCES:
[1]. Adil Baitenov, Alexander Iakovlev, Dmitriy Beznosko, "Technical manual: a survey of scintillating medium for high-energy particle detection," arXiv preprint arXiv:1601.00086, 2016/1/1
[2] MELZ-FEU, 4922-y pr-d, 4c5, Zelenograd, g. Moskva, Russia, 124482 (http://www.melz-feu.ru).
[3] CAEN S.p.A. Via della Vetraia, 11, 55049 Viareggio Lucca, Italy (http://www.caen.it).
[4] Agilent INC., 5301 Stevens Creek Blvd, Santa Clara, CA 95051, United States (http://www.agilent.com).