Understanding Scattering and Energy of Particles in the SNO+ Experiment

Alexandra Huss

August 19, 2013

Outline

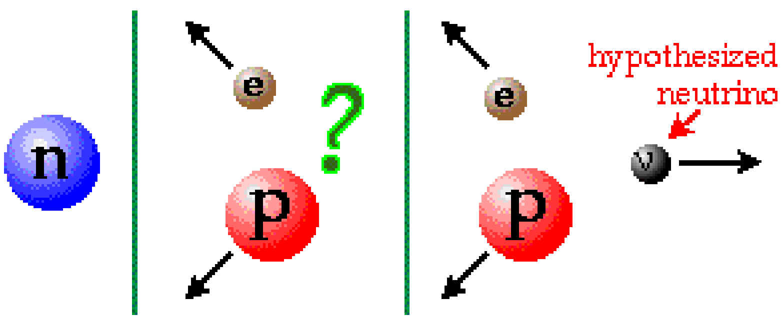
- Brief neutrino history
- The SNO+ Experiment
- Measuring Rayleigh scattering
  - Motivation
  - Methods
  - Results
- Testing light yield vs. energy relationship

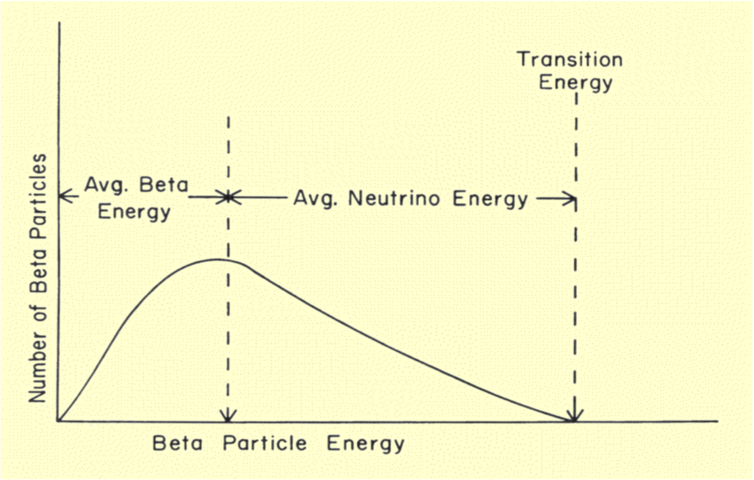
History of Neutrino Detection

1931: Pauli predicts existence of a particle based on beta decay: charge neutral and nearly massless

1932: Chadwick discovers neutron

1933: Fermi coins the neutrino ("little neutral one")



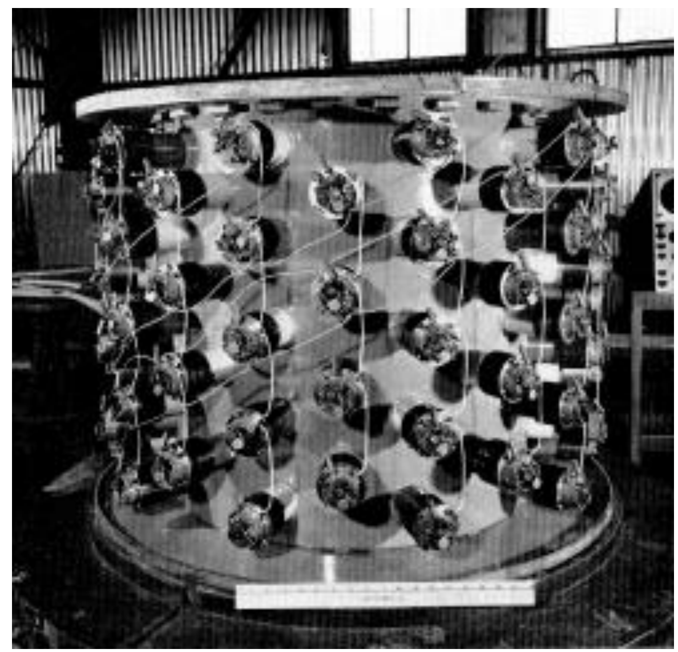


History of Neutrino Detection cont.

1959: Cowan and Reines announce discovery of particle that fits expected neutrino characteristics

Experiment: Beta decay in a nuclear reactor. Resulting gamma ray detection gives evidence of antineutrino

$$\bar{\nu}_e + p \rightarrow n + e^+$$



SNO+

Underground neutrino detector - Sudbury, Canada

Detector with ~800 tons of liquid scintillator composed of linear alkyl benzene (LAB)

~10,000 PMTs

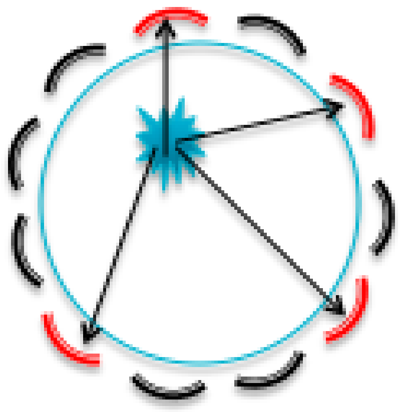
Detection by scintillation rather than Cherenkov process (SNO)

SNO+ Neutrino Detection

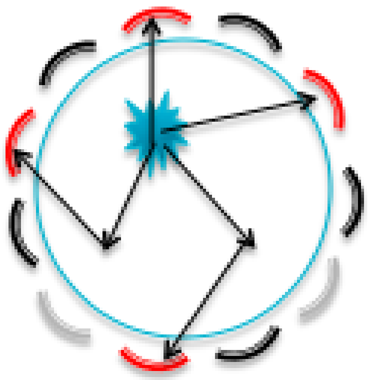
Neutrinos interact with electrons and nuclei in detector to produce charged particle

Scintillator gives off light when a charged particle passes through it

PMTs detect light from event



Rayleigh Scattering: Motivation



Scattering length becomes a problem

Time spectrum of detected photons no longer predictable

Rayleigh Scattering:

Occurs for particles smaller than the wavelength of the light

Result of electric polarizability of particles

- -oscillating electric field of light wave acts on charges in particle causing them to move at same frequency
- -particle becomes radiating dipole whose radiation is seen as scattered light

Rayleigh Scattering: Methods

Intensity of scattered light $\propto \lambda^{-4}$

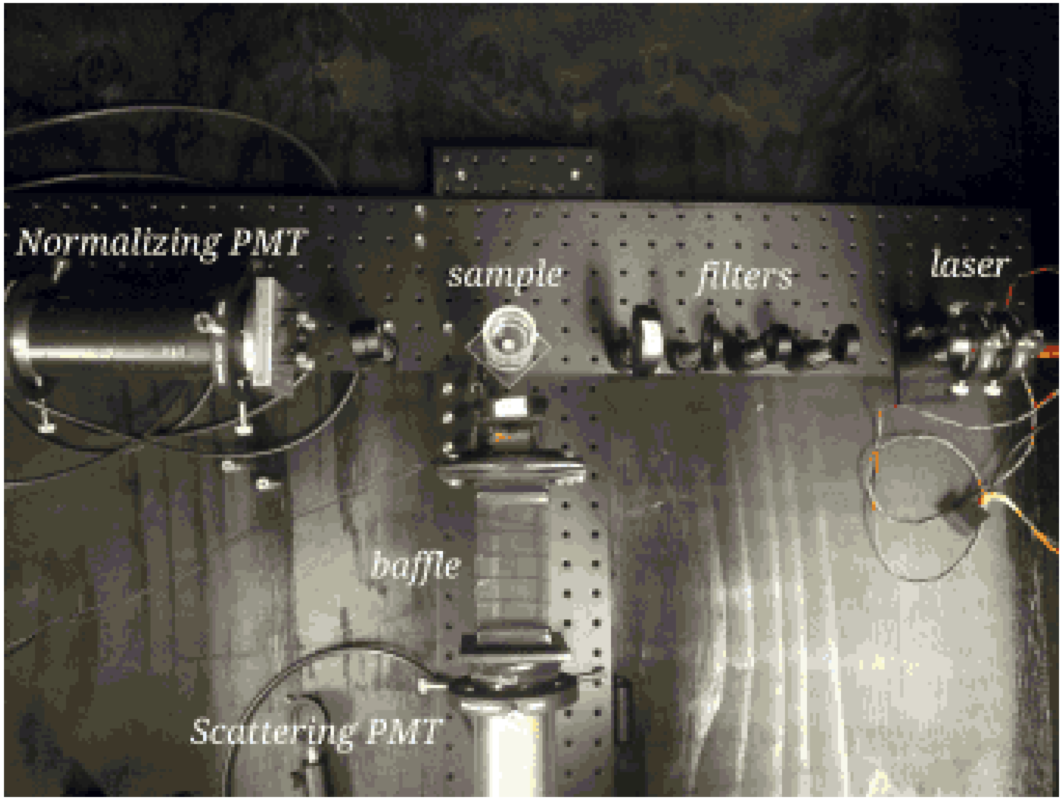
$$I = I_0 \frac{\alpha}{\lambda^4}(1 + \cos^2\theta)$$

To measure scattering length of photons in scintillator:

-collect data for light scattering from scintillator sample at varying wavelengths, angles, polarizations
-plot scattering data as function of wavelength
-fit to Rayleigh function

Rayleigh Scattering: Methods

Apparatus:



Rayleigh Scattering: Methods

Data Collection:

Measurements made at wavelengths 405, 447, 473, 532, 650nm

For each wavelength: angles 45, 60, 75, 90 and polarizations VV, VH, HH, HV

Normalized PMT, Scatter PMT, and dark rate counts recorded

Rayleigh Scattering: Methods

Data Analysis:

•Dead time correction: $$r = \frac{m}{1 - md}$$

•Dark rate subtraction
•Scatter counts/Normalization counts
•Filter correction
•Geometric correction

•Fit to equations:

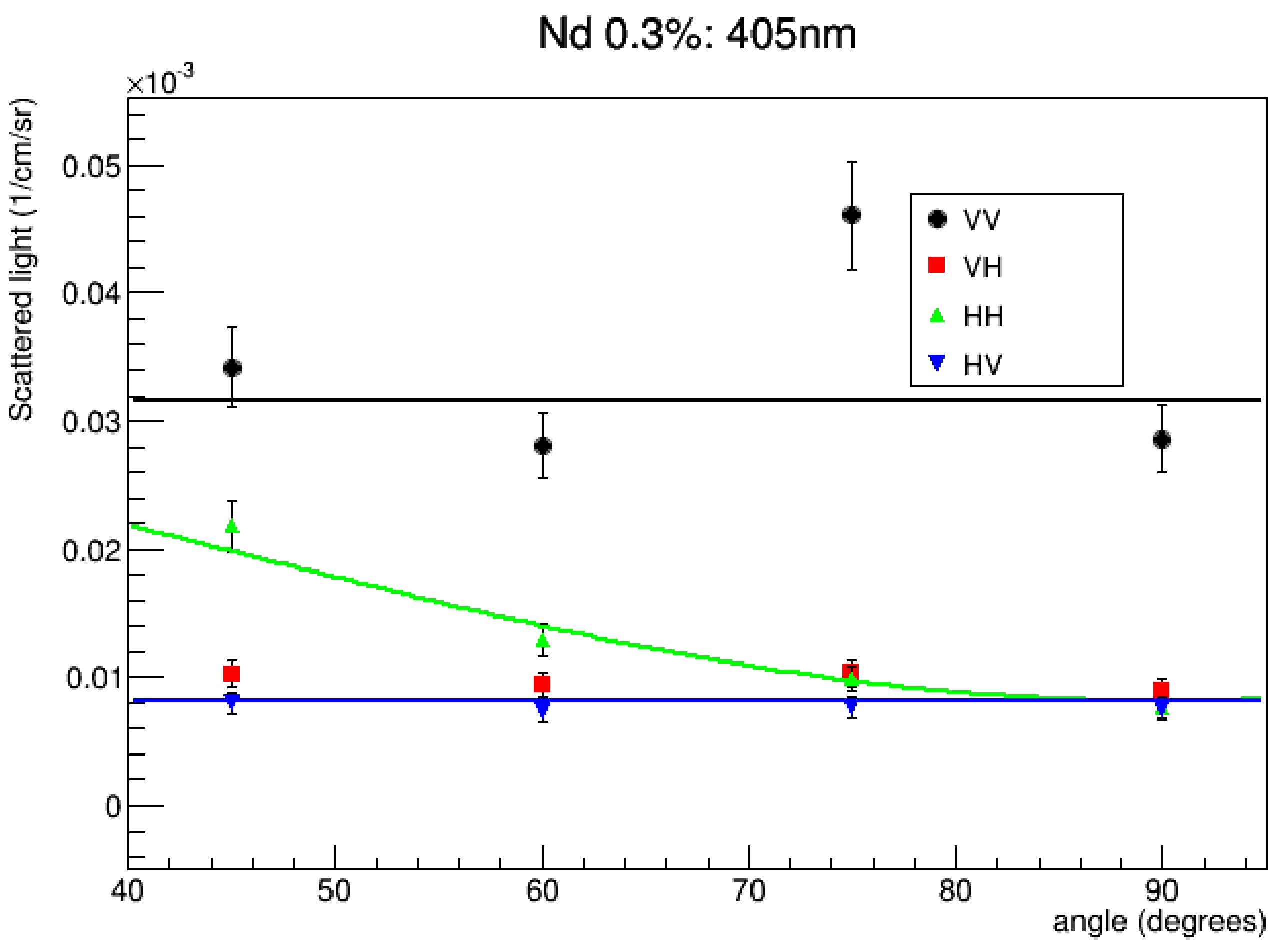
$$VV = \frac{R}{\lambda^4} + A(\lambda)$$

$$VH = A(\lambda)$$

$$HH = \frac{R\cos^2\theta}{\lambda^4} + A(\lambda)$$

$$HV = A(\lambda)$$

Rayleigh Scattering: Results



Rayleigh Scattering: Results

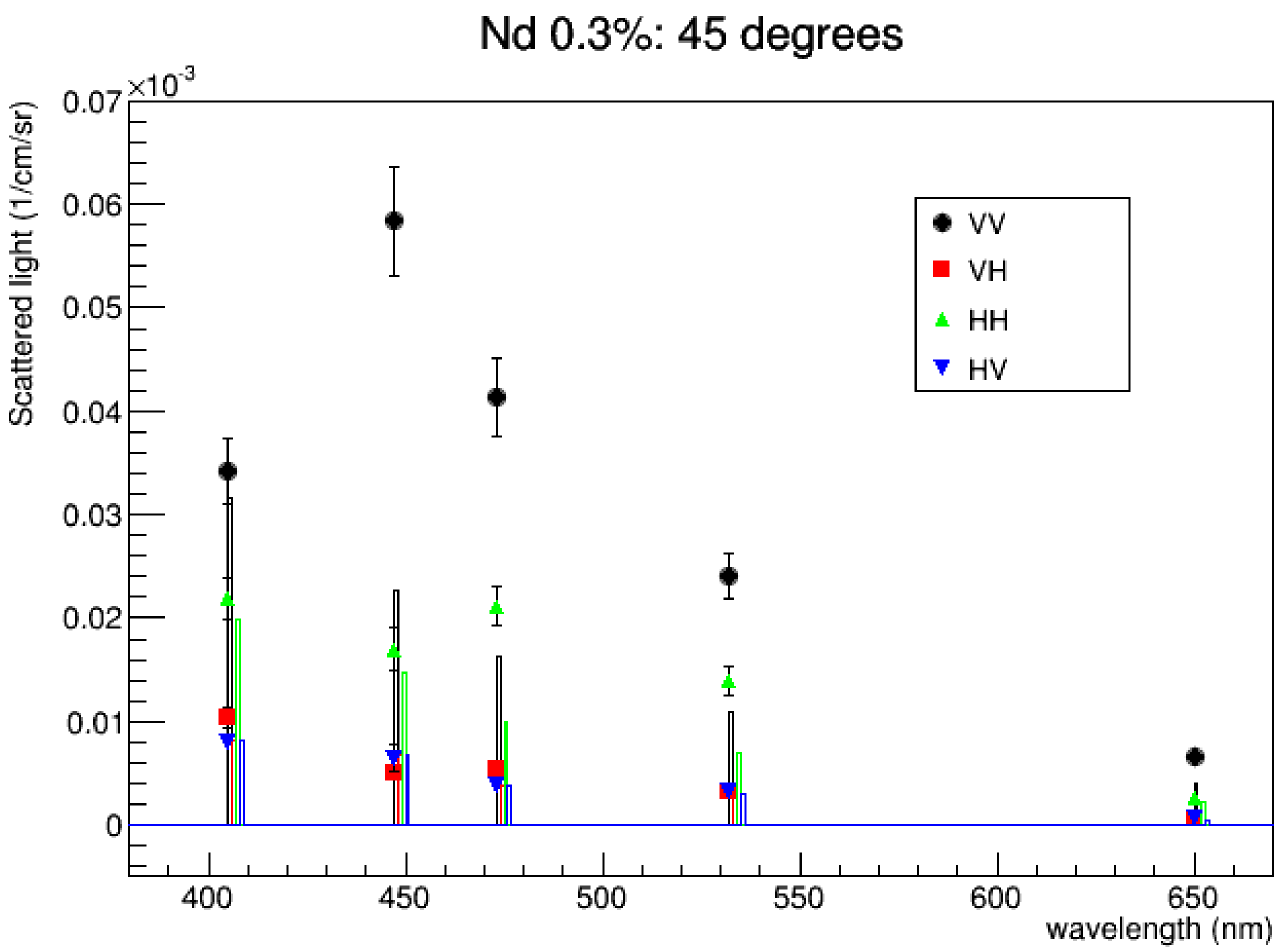
Calculated Rayleigh scattering lengths at 405nm:

Nd 0.3% +BisMSB: 19.6 m

Te 0.3% +BisMSB: 4.3 m

Nd 0.3%: 25.5 m

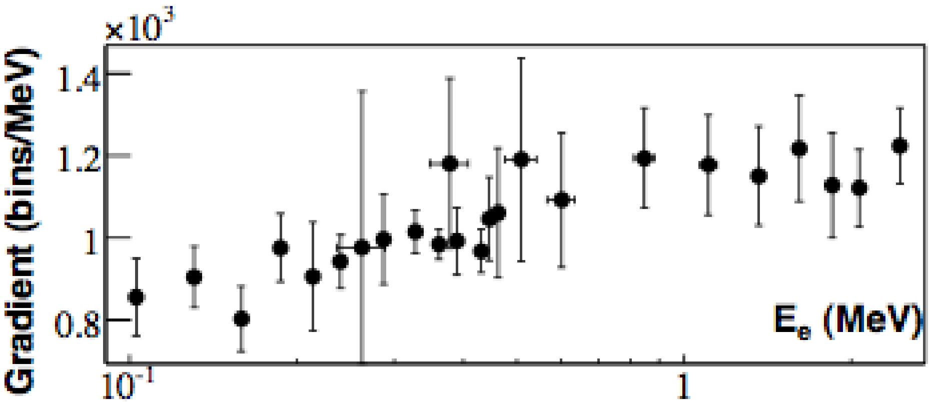
Rayleigh Scattering: Results

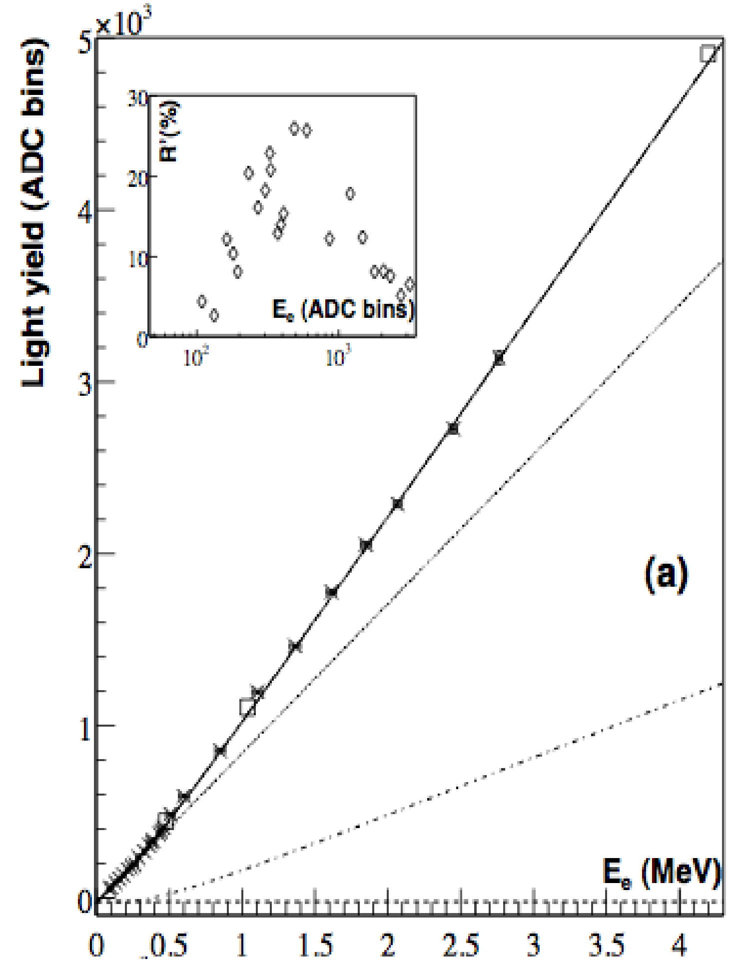


Possibility of Mie scattering to be investigated further

Light yield vs. Energy

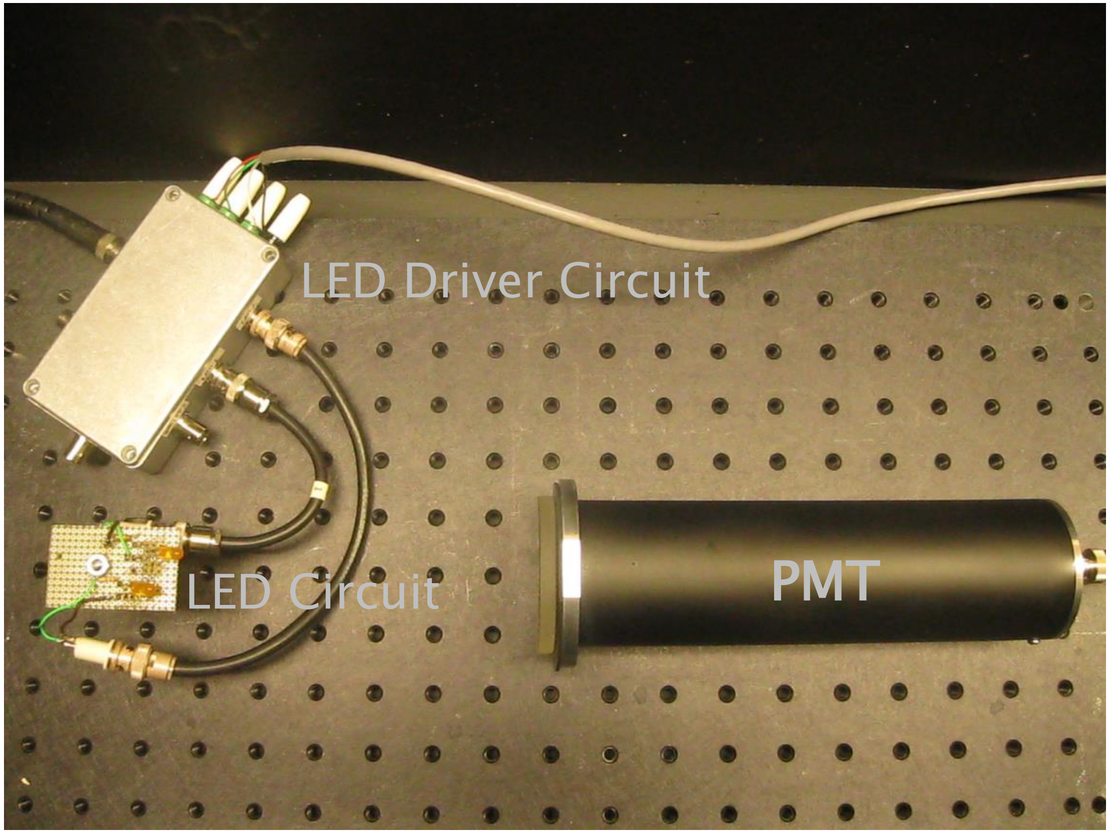
Need to understand properties of scintillator down to SNO+ energy threshold ~0.2 MeV



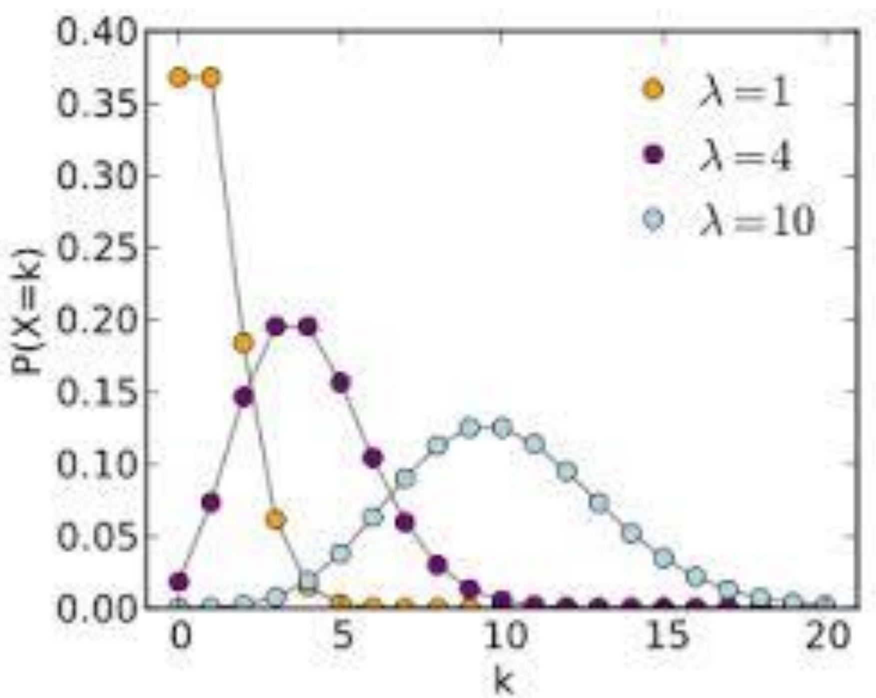


Light yield vs. Energy: Methods

Apparatus:



Light Yield vs. Energy: Methods



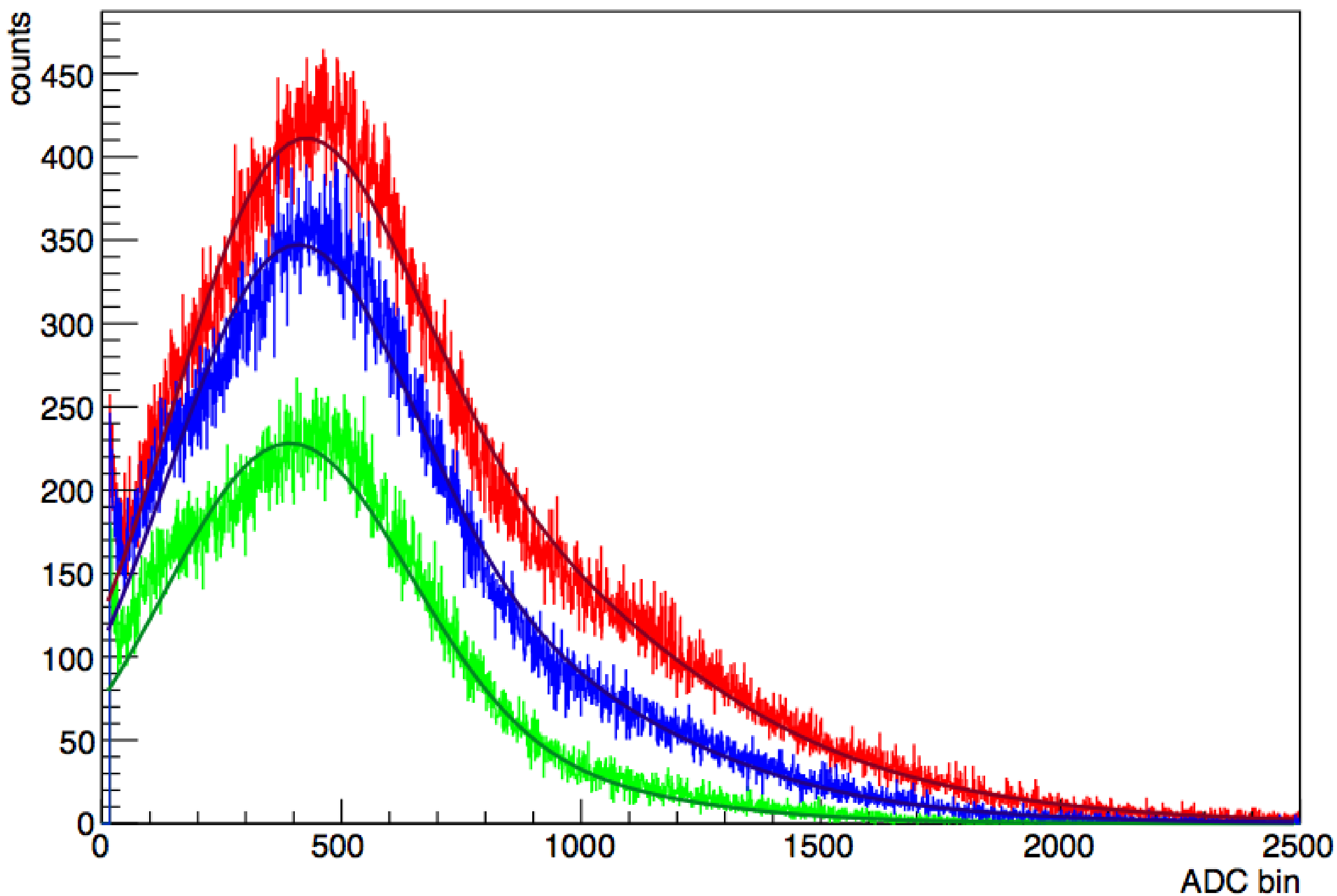
Single photon peak is underlying Gaussian

$$P(x) = \frac{e^{-\left(\frac{(x-\mu)^2}{2\sigma^2}\right)}}{\sigma\sqrt{2\pi}}$$

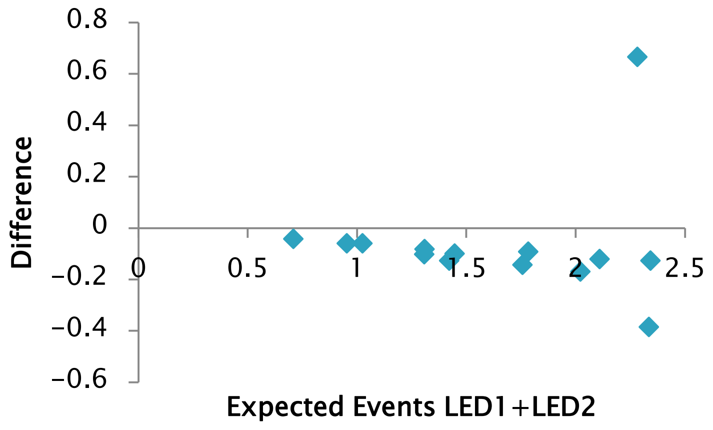
Detection of photons described by Poisson distribution

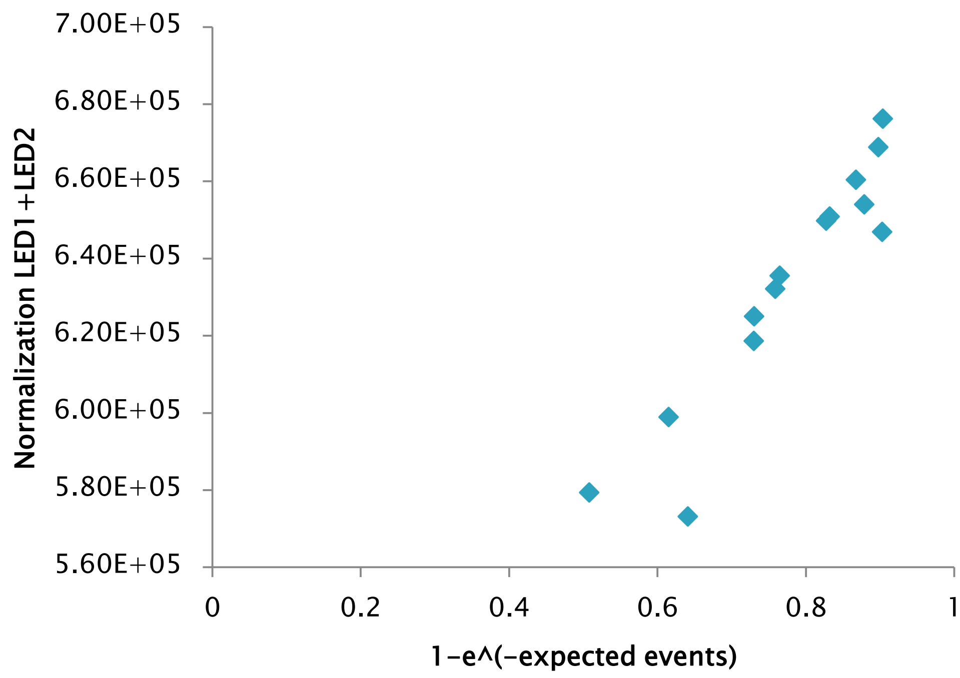
$$P(k;\lambda) = \frac{\lambda^k e^{-\lambda}}{k!}$$

Light Yield vs. Energy: Results



Light Yield vs. Energy: Results





Moving Forward

Fine tune electronics to decrease noise

Calibrate higher photon peaks from single photon peak

Light intensity as function of single photon

Acknowledgements

Thanks to:

Dr. Nikolai Tolich
Tim Major
SNO+ collaboration

Deep Gupta
Alejandro Garcia

Linda Vilett
Janine Nemerever

National Science Foundation

References

H. Wan Chan Tseung, J. Kaspar, N. Tolich. Measurement of the dependence of light yields of linear alkylbenzene-based and EJ-301 scintillators on electron energy. *Nuclear Inst. and Methods in Physics Research*, A 654, 2011, pp. 318-323

Leo, W.R. *Techniques for Nuclear and Particle Physics Experiments: A How-To Approach* Springer_Verlag, Germany (1984) 79-82.