SURF Presentation 2016

Slide One – Hello my name is Ariel Hasse and I am in the class of 2019 at Caltech studying physics. I am currently a SURF student in Professor David Hitlin’s group in high energy physics.

Slide Two – In high energy experiments large calorimeters are constructed in accelerators to help identify particles. These are often made of inorganic scintallors, or large crystals. For my research I am studying Barium Fluoride crystals and Birk’s Law. As particles interact with the crystal photons multiply through the lattice from electron excitation. The energy of the photons are recorded and the experimental value from the source can be verified.

An important factor in scintillation time is the slow and fast component of BaF2. These are two mechanisms of scintillation, which are at different wavelengths that determine how quickly photons are emitted. In accelerators BaF2’s fast component is very useful for measurement, however separating the fast component from the slow component is difficult. Ultimately this experiment will find the ratio associated with the quenching factor for these large-scale experiments like Mu2e.

Slide Three- As the particles travel through the inorganic scintillator, Birk’s Law describes the amount of light emitted for a given energy lost. The ratio of dispersed energy is dependent on the mass of the particle; this is known as the quenching factor. In the equation it is noted as kb. The Quenching Factor is determined by the ratio of fast and slow components of the Barium Fluoride Crystals. The Quenching Factor is important to understanding the energy loss of particles of varying masses and energies in particle physics experiments.

Slide Four- Our set-up includes a light proof data collection box, a photomultiplier tube (PMTs) (one of the three used in the experiment), a power generator, a temperature probe, a radioactive source, Caen, a data synthesis software, and the monitor display. Depending on the rate of decay and the light spectrum of the PMT we would place a source in the light tight box with the PMT powered and connected over a period of time. We used five sources Cs-137, AmBe 241, Na-22, Co-60, and a natural radium impurity Ra 226.

Slide Five- The data came in like this. The x axis represents an amount of energy. The scale is determined by the binning size and voltage. The y axis is a count of how many times the PMT has “read” a photon of that energy. The position of these peaks represents the energy of the sources. Some sources have more than one emission, such as Na-22 where we expect peaks at 511 keV and 1.19 MeV.

Slide Six- Now before I even collected data I created a python pipeline to analyze my results. The histogram can be output as a txt file that can be easily plotted. I also created a program to make a plot of the temperature to ensure the room was stable while I was not in the laboratory. Using the data and the optimize package from the scipy library I was able to make Gaussian fits to the peaks so I could determine the peak position and width.

Slide Seven – Here I have all of the fits for each source with the UV Full Extended PMT. The Gaussian fit allows me to extract the peak position. This value is of the channel that the source’s energy was on the scale of the x-axis. The width is also important as it helps determine the resolution, the standard deviation. The resolution gives me an idea of the clarity of the peak and is generally below five percent.

Slide Eight – For each of the sources the emission energy of the decaying particle is known in keV. The values are listed here. Using the known values and the measured channel values a conversion factor between channels and keV is established. This is the ratio one would expect any source to convert to if detected by this PMT at this voltage. To determine this ratio I used the data from Cs, Na, AmBe, and Co since they are all gamma and electron decay (similar in mass).

Slide Nine – The radium impurity however is alpha decay. The four peaks are known and are as follows. However using the conversion from channels to keV we find that they are 3 times the amount of an average. This plot shows the linear function this represents, also known as the Quenching Factor. The value changes linearly with energy of the particle and is consistent.

Slide Ten – The mechanism of the quenching factor is not well understood however it can be predicted from the ratio of the fast and slow components of Barium Fluoride. A convolution of the quantum efficiency and the wavelengths seen the amount of light produced by each fast and slow in the crystal can be determined. Here the convolution of the UV Extended Solar Blind is shown. The ratio of the fast and slow component can be represented linearly. The coefficient that determines the ratio is found from the intersection of this relationship for three PMTs.

Slide Eleven- We used the UV Extended Full Spectrum, Solar Blind, and the Full Spectrum with a low pass filter. Each of these PMTs can see different wavelengths and therefore see different ratios of the fast and slow components. The ratios of energy from the fast and slow components from multiple photomultiplier tubes with varying quantum efficiency as a function of wavelength, determine the final quenching factor.

Slide Twelve – I have collected a full set of data for the first PMT and am currently in the collection process for the last two. Once I have all of my data I will be able to determine the Quenching factor ratio for alpha decay and the Barium Fluoride crystal. This in itself will be useful for data for hep experiments. However I will continue an investigation of the Quenching Factor to study the physical mechanisms involved. As I mentioned not much is known particularly in inorganic scintillators, crsytals, and some analysis could provide deeper insights into the phenomenon and Birk’s Law.

Slide Thirteen- Here are my references along with photo credits

Slide Fourteen- And of course I’d like to thank, so and so.

Thank You