**Particle interaction with matter**

Understanding particle nature in matter is essential in neutron detection. One must be mindful of materials utilized in particle detectors and how they effect its performance. Knowing which interactions take place makes it possible to choose proper material for neutron converters (to maximize yield) and sensitive volumes (to optimize effectiveness), as well as surrounding electronics and other components (to minimize interference), of the detector. All types of particles, heavy, light and neutral, are present in neutron detection, though some are more interesting than others, specifically neutrons and signal generating particles.

Particles of interest in a gadolinium-based semiconductor neutron detector are neutrons, electrons and gammas (i.e. photons). Neutrons are absorbed in gadolinium and produce electrons and gammas. Reaction products act as neutron indicators and generate a signal by energy loss in the detectors sensitive volume.

Particles traversing matter lose energy and/or are scattered from their original path. Particles characteristic determine which types of interaction take place and thus also its propagating nature. For instance, particles with electric charge behave quite differently from neutral ones. Charged particles experience intervening Coulomb forces and slow down or stop, while neutral particles are indifferent to such forces and travel rather large distances in comparison.

It is therefore necessary to distinguish particles of different nature. The two major groups of particles are charged and neutral.

**CHARGED PARTICLES**

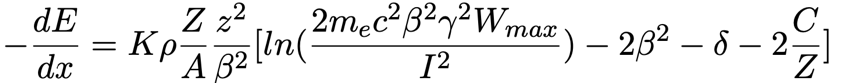
Particles with electrical charge are subject to electromagnetic forces. Matter is made up of atoms, which composite atomic electrons and nuclei. Atomic constituents are each surrounded by an electric field and in the path of a traversing particle, causes deacceleration and divergence from its original trajectory. Energy loss mechanisms of a charged particle are:

Again, one must distinguish based on particle properties, this time, namely mass.

The mass of a "heavy" particle is one atomic unit or greater. This includes protons, alpha and other ions. That leaves electrons and positrons as "light" particles, with an atomic mass is ... Less than protons. Heavy particles (e.g. ions) are less effected by a nuclei electric field than light particles (e.g. electrons). Elastic scattering of the nuclei effect both heavy and light, however, the impact is greater for the latter.

**Heavy charged particles and Bethe-Bloch**

Though there are several types of interactions, heavy charged particles mainly lose energy due to inelastic collisions with outer-shell electrons. The Bethe-Bloch formula describes their average energy loss per unit length:



Noteworthy symbols in the formula are B (representative of incident particle speed) and z (charge of incident particle). Remainding paramters are listen in table ??

B = v/c and thus, according to bethe-bloch, mean energy loss dE/dx is inversely proportional to v^2, the particle speed squared. As particles slow down their speed decreases and energy deposition increases, until fully at rest. The other dependency z, shows how particles of heavier charge ionize material more effectively. (rewrite)

Electrons

Other interactions

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**6/29/20**

**Electron**

Light particles, like electrons and positrons, lose energy via other interactions in addition to elastic scattering. Total energy loss is a combination of radiational and collisional loss.

[eqation]

Collisional loss can be described by a modified Bethe-bloch. As for heavy particles, workings of **collision** still apply for light particles, however, assumption of large incident particle mass and non-deviating trajectory are no longer valid and must be corrected for. Also, in case of incident electrons, collision are between identical particles. Taking their indistinguishability into account changes a couple of terms in the formula, notably maximum allowed energy transfer $W\_max = \frac{T\_e}{2}$ for electrons of kinetic energy $T\_e$.

As mentioned, light particles also lose energy by radiation. Electric fields of nuclei cause particles to accelerate and consequently emit electromagnetic radiation. Negatively charge electrons are attracted by positive nuclear electric fields and deviate from their straight-line path in a curved manner.Path divergence causes directional change of velocity vectors, i.e. acceleration.

Accelerating charged particles radiate electromagnetic radiation known as bremsstrahlung (German for breaking radiation). At the expense of radiating photons, particles lose kinetic energy and slow down. All radiation can be lost though bremsstrahlung in only one or two photons. This causes same energy electrons to greatly vary in path length.

**COME BACK TO LATER:** Energy loss by collision varies logarithmically with energy while probability of radiation loss increases nearly linearly with energy; small for few MeV and in most material dominates above a few tens of MeV.