Cosmic muons and relativity

The mean energy of the muons reaching sea level is about 4 GeV.

Assume that $N_0 = 1 \times 10^6$ muons are created at 15 km height. Calculate classically and relativistically the number of muons which have survived at sea level.
Assume that the muons do not loose energy during their flight.

Muon energy

Determine momentum, energy and kinetic energy of a muon created from a pion decaying at rest.

Asymmetry

Determine the μSR asymmetry from the Forward and Backward detectors.
We will admit that the Forward and Backward detectors are defined with respect to the beam direction.

Muon polarization with field

Derive the time evolution of the muon polarization $P(t)$ (projection along the initial polarization) in a magnetic field $\mathbf{B}_\mu$ forming an angle θ with respect to the initial polarization.

Polarization

Compare the NMR and μSR polarization by deriving the average polarization of an ensemble of nuclei with spin I, in a magnetic field B and a temperature T.

Magnetism in a polycrystal as seen by μSR

Derive the time evolution of the muon polarization $P(t)$ for a muon ensemble seeing a single value of the internal field in a polycrystalline magnet.

Incommensurate magnetic structure

Derive the time evolution of the muon polarization $P_z(t)$ for a muon ensemble seeing a modulation of the internal field which is incommensurate with the crystallographic structure.
Assume that the internal field point along the x direction and that the initial muon polarization is along z.

In a simple model, the value of the field at the muon-site is given by

$$B_\mu = B_{\max} \sin(2\pi\, k\, r_\mu)$$

where k represents the value of the $\mathbf{k}$ vector of the magnetic structure (here we assume that $\mathbf{k}$ and $\mathbf{r}_\mu$ are parallel).

Field distribution in a type II superconductor

Determine the relation between the second moment of the field distribution in the Abrikosov phase and the penetration depth. Assume that the coherence length is much smaller than the penetration depth