## 2. Landau theory

For a particle of mass $m_x$ traversing a thickness of material $\delta x$, the Landau probability distribution may be written in terms of the universal Landau function $\phi(\lambda)$ as[1]:

$$f(\epsilon, \delta x) = \frac{1}{\xi}\phi(\lambda)$$

where

$$\begin{aligned}
\phi(\lambda) &= \frac{1}{2\pi i}\int_{c+i\infty}^{c-i\infty} \exp\left(u \ln u + \lambda u\right) du \qquad c \geq 0 \\
\lambda &= \frac{\epsilon - \bar{\epsilon}}{\xi} - \gamma' - \beta^2 - \ln\frac{\xi}{E_{\max}} \\
\gamma' &= 0.422784\ldots = 1 - \gamma \\
\gamma &= 0.577215\ldots \text{(Euler's constant)} \\
\bar{\epsilon} &= \text{average energy loss} \\
\epsilon &= \text{actual energy loss}
\end{aligned}$$

### 2.1. Restrictions

The Landau formalism makes two restrictive assumptions:

1. The typical energy loss is small compared to the maximum energy loss in a single collision. This restriction is removed in the Vavilov theory (see section 3).

2. The typical energy loss in the absorber should be large compared to the binding energy of the most tightly bound electron. For gaseous detectors, typical energy losses are a few keV which is comparable to the binding energies of the inner electrons. In such cases a more sophisticated approach which accounts for atomic energy levels[4] is necessary to accurately simulate data distributions. In GEANT, a parameterised model by L. Urbán is used (see section 5).

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