Estimation of the Pion Rates for the Moller Experiment

Yufan Chen and Neven Simicevic*
Center for Applied Physics Studies
Louisiana Tech University, PO Box 10348, Ruston, LA 71272

Abstract

In this report we study the pion rates for the Moller experiment.

* Address correspondence at Louisiana Tech University, PO Box 10348, Ruston, LA 71272
Tel: 1.318.257.3591
Fax: 1.318.257.4228
E-mail: neven@phys.latech.edu

II. The Moller experiment kinematics

Kinematics taken from the proposal of the Moller experiment is shown in Figure 2. To accept all (forward and backward) Møller electrons in the polar angle range of 60 to 120 degrees in the center of mass, the polar angle and the momentum ranges in the laboratory frame are calculated for the forward Møller electrons to be 5.5 to 9.5 mrad (0.315 to 0.54 degrees) and 5.5 to 8.25 GeV respectively, and the corresponding ranges for the backward Møller electrons are 9.5 to 17 mrad (0.54 to 0.974 degrees) and 2.75 to 5.5 GeV.

The latest design of the Moller experiment collimators restrict polar angular acceptance between 0.346 and 0.96 degrees. With this restriction we have recalculated the Moller experiment kinematics. The results are shown in Figure 3.

The collimators restrict polar angle range from 64 to 120 degrees in the center of mass, and the polar angle and the momentum ranges in the laboratory frame are calculated for the forward Møller electrons to be 0.346 to 0.552 degrees and 5.5 to 7.9 GeV respectively, and the ranges for the backward Møller electrons to be 0.552 to 0.96 degrees and 2.75 to 5.5 GeV.

III. The Moller cross section rates

The electron rates for the Moller scattering are estimated to be 153 GHz in the experiment proposal, and 135 GHz in Ref. [MOLLER 2012]. Assuming the collimators center-of-mass polar angle restricted range of 64 to 120 degrees, and the new momentum acceptance of 2.75 to 7.9 GeV we will here recalculate the theoretical Moller rates. The Moller cross section in the center of mass between 64 to 120 degrees is shown in Figure 4.

We will calculate the Moller experiment rates separately for forward and backward scattered electrons taking into consideration that the experiment is design to detect either of them, but not both. The luminosity will be taken from Table 1 since it is the same we obtained.

The results are as follows:

- Forward electrons rate: **76 GHz**
- Backward electrons rate: **96 GHz**

For a total rate of **172 GHz**. The rate is not symmetric and it is larger than the rate estimated in Table 1.

IV. The Rutherford cross section rates

In addition to the electron rates due to the Moller scattering there is also electron-proton scattering reaction channel. For the polar angle of less than 1 degree the rates for this channel can be estimated using the Rutherford scattering cross section.

The results are as follows:

- Rate in the 0.346 to 0.552 degrees region (forward Moller electrons): **30 GHz**
- Rate in the 0.552 to 0.96 degrees region (backward Moller electrons): **13 GHz**

For a total rate of **43 GHz**.

V. The total electron rates

Adding both, the electron-electron scattering rates calculated using Moller cross section and electron-proton scattering rates calculated using the Rutherford cross section we obtained the total electron rates.

The results are as follows:

- Rate in the 0.346 to 0.552 degrees region (forward Moller electrons): **106 GHz**
- Rate in the 0.552 to 0.96 degrees region (backward Moller electrons): **109 GHz**

For a total rate of **215 GHz**.

VI. Electron rates obtained using FLUKA

Using FLUKA to obtain electron rates is straight forward. Electrons are propagated through 150 cm long liquid hydrogen target using all the appropriate reaction channels defined in FLUKA. The fluence of the electrons propagating through the target is shown in Figure 5.

The downfall is that the obtained electron rates include both electron-electron and electron-proton scatterings. As seen in Figure 6, they can be kinematically separated but this require detail knowledge of the spectrometer and the detectors acceptance.

The results are as follows:

- Rate in the 0.346 to 0.552 degrees region (forward Moller electrons): **102 GHz**
- Rate in the 0.552 to 0.96 degrees region (backward Moller electrons): **112 GHz**

For a total rate of **214 GHz**.

The results obtained using FLUKA and previous "theoretical" calculations are similar:

- Difference in rate in the forward Moller electrons kinematical region: **- 3.9 %**
- Difference in rate in the backward Moller electrons kinematical region: **+ 2.7 %**

For a total difference in rate of **- 0.5 %**.

VII. The pion phenomenological rates

The pion rates will be estimated using the Wiser code for the previous defined acceptances: polar angle range from 64 to 120 degrees in the center of mass, the polar angle and the momentum ranges in laboratory system for the forward Møller electrons of 0.346 to 0.552 degrees and 5.5 to 7.9 GeV respectively, and for the backward Møller electrons of 0.552 to 0.96 degrees and 2.75 to 5.5 GeV.

The results normalized to Moller electron rates are as follows:

- Pion rate in the forward electrons range: **0.024 GHz or 0.031%**
- Pion rate in the backward electrons range: **0.105 GHz or 0.110%**

For a total rate of **0.129 GHz or 0.075%.**

VIII. Pion rates obtained using FLUKA

Using FLUKA to obtain pion rates is straight forward. Pions are produced by electrons propagating through 150 cm long liquid hydrogen target using all the appropriate reaction channels defined in FLUKA. The pion fluence is shown in Figure 7. Pion kinematics and rates are shown in Figure 8.

The results normalized to Moller electron rates are as follows:

- Pion rate in the forward electrons range: **0.0046 GHz or 0.006%**
- Pion rate in the backward electrons range: **0.0225 GHz or 0.023%**

For a total rate of **0.0271 GHz or 0.016%.**

FLUKA predicts ~4.7 times less pions than the Wiser code.