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The positron-positron Moller scattering: call for the experiment

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The luminosity of the recently reported laser produced positron beams is comparable to the one used to measure the electron-electron Moller scattering in the center of mass geometry. Therefore the technology allows to measure the scattering crossection of relativistic positrons on positrons coming from the opposite side, that is never observed so far positron-positron Moller scattering. The apparent asymmetry of the universe with respect to the charge conjugation can be explained by the violation of the Pauli spin-statistics theorem for the antimatter. The experiment will rule out this possibility.

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The derivation of the Moller scattering crossection[1, 2] is the standard part of every QED course and textbook. The experimental data related to the measurement of the electron-electron scattering is available in just a dozen of papers spread over nearly fifty years[3]. It is not surprising therefore, that evidences for positron-positron elastic scattering have not been published so far by any of teams having access to positron beams.[4, 5]

The most accurate measurement of the Moller crossection was performed in the center-of-mass geometry (The measurements in the laboratory system suffers from large spread of the energy of the scattered electrons). The typical setup had two beams of the accelerated electrons coming from two opposite sides.[6–9] In these experiments the accuracy was sub 1% due to large statistics (few thousands registered collisions). The reported luminosity of the electron beams from the storage rings was ∼100mA focused on spot of ∼100nm, that is $\sim 10^{26}/\mathrm{cm}^2\mathrm{sec}$.

Today the petawatt laser shot creates the most dense ever reported positron beam[10–14]. The peak observed positron density in the beam is $10^{16}\mathrm{cm}^{-3}$ corresponding to the luminosity of $\sim 10^{26}/\mathrm{cm}^2\mathrm{sec}$ and therefore comparable with the luminosity of the electron beam used in the most advanced Moller scattering experiments with electrons. The focusing of the laser spot, and therefore the width of the positron beam, are in the range of 10-30um. These values are ∼100 times worse than that of electrons originating from the accelerator storage ring, however this is not an issue once luminosity goal has met.

The experiment with positron-positron Moller scattering in the center-of-mass system would require two lasers creating colliding positron beams. Therefore it can be challenging for experimental setup, it can be even more challenging to get two simultaneous pulses from two lasers.

The positron-positron Moller scattering in the laboratory system is relatively simpler; the laser produced positron beam need to hit the target; e.g. cold positron or positronium plasma. Both trapped positron and positronium plasmas are accessible to experimentalists[4, 5] at maximal densities of $\sim 10^{10}\mathrm{cm}^{-3}$. The scattering rate will be determined the highest density component, in this case the laser produced positron beam. The plasma should have enough positrons within the size of the laser spot times the length of pass of the incident beam through the plasma. This is not an issue for typical plasma trap dimensions.

The universe is asymmetrical with respect to amount of observed matter and antimatter. This apparently contradicts the charge conjugation symmetry converting matter to antimatter and vise-versa. This paradox can be resolved by the assumption that the charge conjugation flips the particle statistics[15] (see also [16]). In order to rule out or confirm this theory one should carry out an independent experiment with positron-positron interaction. Unfortunately by the time of writing this manuscript none observed neither multi-positron anti-atoms, nor positron-positron elastic scattering.

The positron-positron scattering crossection should be the same as given by [2], Eq. (81.10) if the positrons are fermions. In the opposite case of the commuting positrons one should change sign of the last term in braces in [2], Eq. (81.7). For reference the overall result in the center-of-mass system is

$$\begin{aligned} d\sigma &= \frac{(\varepsilon^2+p^2)^2}{4\varepsilon^2 p^4} e^4 do \left[\frac{4}{\sin^4(\theta)} + \frac{p^4}{(\varepsilon^2+p^2)^2} \right. \\ &\left. - \frac{1}{\sin^2(\theta)} \left\{ \begin{array}{ll} 3 - 4p^4/(\varepsilon^2+p^2)^2 & \text{fermions} \\ 5 - 4\varepsilon^4/(\varepsilon^2+p^2)^2 & \text{bosons} \end{array} \right. \right] \qquad (1) \end{aligned}$$

where ε is the energy of particles before and after scattering (preserved), p is the momentum, θ is the scattering angle and e is the electron charge. The experiment error should be much lower than $|d\sigma_f - d\sigma_b|/(d\sigma_f + d\sigma_b) \sim \sin^2(\theta)$ in order to provide unambiguous confirmation of the Pauli principle for positrons.

To summarize, the positron-positron scattering experiment is proposed for verification of the Pauli principle and QED accuracy for the antimatter. The analysis shows that the modern technology is ready to test the Moller scattering for positrons, the available density of the positron beams is similar to that used to verify the Moller formula for electrons. In case when the Pauli principle will not be confirmed for positrons, this can explain why the antiworld does not exists.[17]

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