

## 1 Project goal

Unanswered questions of the universe are the motivation of the ongoing research in theoretical and experimental particle physics. One of them is the question about the origin of matter antimatter asymmetry in the universe. If there would be equal amount of matter and antimatter that would come in to contact, annihilate and disappear in the form of energy. But why there is more matter than antimatter in universe? A Russian physicist proposed that the fundamental symmetry of Nature must be violated to solve this puzzle. It is found that certain symmetries were assumed to be true in physics but then small violations were observed in some interactions. Studies are going on to search for violation of symmetry between fundamental particle and its antiparticle which are the building blocks of matter and antimatter in the universe. One of the system suitable to study matter antimatter symmetry in Nature is positronium that constitutes a particle  $e^-$  and its anti particle  $e^+$  in one system. The aim of the project is to search for symmetry violation in the decays of positronium, which is a pure leptonic system, under combined charge conjugation and parity (CP) transformation and charge conjugation, parity and time reversal (CPT) transformation. This can be done by measuring CP and CPT sensitive angular correlation operators.

## 2 Description of research

The proposed test will be performed with a photon detector originally created as a prototype of the first Positron Emission Tomography medical imaging scanner using plastic scintillators named as J-PET, constructed at Jagiellonian University, Krakow, Poland. This detector allows to detect the annihilation photons from positronium decays and perform symmetry test in the same system consisting of particle and antiparticle. Further study would be carried out by measuring an angular correlation operator that is odd under both CP and CPT symmetry transformation. Due to this property, if positronium annihilations are symmetric with respect to CP and CPT conjugations, the mean value of such angular correlation would be equal to zero. Therefore, observation of any non-zero average correlation would constitute a proof of symmetry violation. Operators involved in the study gives the angular distribution between the spin of positronium and momentum of annihilating photons.

## 3 Reasons for attempting a particular research topic

The proposed test is the first ever measurement of CP and CPT violation sensitive operator in positronium decays till date. Other angular correlations were measured before but never this one which is sensitive to violations of both CP and CPT at the same time. Measurement of this correlation is challenging because of its sensitivity to various experimental conditions. However, the simulations and experiments conducted with positronium in the J-PET detector to date allowed to understand all the experimental factors affecting such a measurement to a large degree of precision, allowing it not only to measure this angular correlation operator for the first time but also to exceed the precision of previous measurement of other angular correlations in positronium decays.

## 4 Substantial results expected

The aforementioned angular correlation would be measured for the first time, resulting either in determination of levels of symmetry violation or in posing statistical limits on CP and CPT violating effects in case of no observed violation. Moreover, the sensitivity of the proposed measurement is expected to exceed published measurements of other angular correlation operators in positronium decays by more than a factor of 10.