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Measurement of the pion mass from X-ray spectroscopy of exotic atoms

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Collaboration

Pion mass

Abstract content

X-ray spectroscopy of exotic atoms allows the determination of the mass of short-lived negatively charged unstable particle like muons, pions, or kaons from the energies of characteristic X-ray radiation. Pions are captured by the target atoms in a highly excited state and a de-excitation cascade takes place accompanied by Auger and radiative emission. Auger emission is dominant at the beginning of the cascade process, with the shell by shell ejection of the electrons, when the X-ray emission take place mainly for lower level de-excitation. The mass of the pion is extracted by the accurate measurement of X-ray photons corresponding to transitions between levels neither affected by strong-interaction effects nor by remaining electrons. The best conditions are found in the medium part of medium Z atoms which corresponds to the few keV range for X-ray transitions. The actual reference value of the pion mass from the Particle Data Group has an accuracy of 2.5 parts per million (ppm) and is based on two high-accuracy crystal spectroscopy of pionic magnesium and pionic nitrogen. In the case the πMg, the use of a solid target induces a continuous electron refilling during the de-excitation cascade and an assumption on the number of remaining electrons has to be done to extract the pion mass value from the $(4f-3d)$ transition energy measurement. This is not the case when a gaseous target is used as in the measurement of πN atoms where the $(5g-4f)$ energy transition was measured with respect to Cu˜Kα fluorescence radiation. In this case, the accuracy was limited by the complex structure of the broad copper calibration line.
Here we present a new experiment performed at the Paul Scherrer Institut that resumes the strategy of the gas target measuring the πN $(5g-4f)$ transition but exploiting the almost coinciding narrower μO $(5g-4f)$ transition as reference. With an uncertainty of 0.033ppm, the mass of the muon provides a very high accuracy of the reference energy (1 meV). The πN and μO transitions are measured simultaneously with a Johann-type spectrometer equipped with a spherically bent Si(220) crystal and a dedicated array of 6 x-ray CCDs. The simultaneous measurement minimizes possible systematic shifts during the unavoidably long measuring periods.

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