Reinforcement of the proton radius puzzle

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A new value of the proton radius was published in *Science*[1] (January 2013), using measurements of different muonic hydrogen transitions, 1.7 times more precise and reinforcing the former proton radius value published in *Nature*[2] (2010) by the same team involving two researchers from the University of Aveiro.

The idea of deducing the proton radius by means of hydrogen laser spectroscopy was born in the early seventies. Muonic hydrogen would be used instead of the atomic hydrogen. About 200 times heavier, the negative muon should orbit about 200 times closer to the proton. Hence, the influence of the proton on the atomic energy levels of the muon should be magnified, leading to an unprecedented accuracy of the proton radius determination method. This is achieved by relating the proton radius to the hydrogen Lamb-shift - the transition energy measured.

This measurement was only possible due to the joint effort of 35 scientists from 3 continents in which each team has brought its own expertise in the fields of accelerator physics, atomic physics, laser technologies and detectors.

One of those technical difficulties was the development of a suitable X-ray detector system (see photo 1). The task was realized through the main contribution from the Portuguese team including the I3N-Aveiro researchers (Prof. João Veloso and Dr. Daniel Covita), which proved crucial to the success of the experiment.The experiment took place at the πE5 beam-line of the proton accelerator at Paul Scherrer Institute, Switzerland (see photo 2).

After a long and careful analysis, including values obtain by measuring other muonic hydrogen transitions, the new deduced value for the proton radius, 0.84087(39) femtometers (1 femtometer = 0.000 000 000 000 001 meter), in agreement with the former one published in *Nature*[2] by the same team, turned out to be ten times more precise, but in strong disagreement with the CODATA accepted value (0.8768 femtometers) and at 7 sigma variance with respect to it. Such unexpected difference of about 4% is huge in the QED framework and discussions on possible reasons to explain it are still ongoing. The origin of the large discrepancy between our proton radius and the CODATA value is not yet known.

There are several aspects which are now under scrutiny: previous high-precision measurements, extended and intricate calculations involved and maybe at some point even small readjustments to the world's most precise and best-tested fundamental theory itself – quantum electrodynamics.

Further developments, experimental and theoretical, from different research teams around the world, are ongoing in attempting to contribute to solving the puzzle.

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REFERENCES

1 – A. Antognini et al., *Science* 339 (2013)417
2 – R. Pohl et al., *Nature* 466(2010)213