DIRAC collaboration status report
SPSC, October 2018.
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I. Long-lived states of $\pi^+\pi^-$ atoms.

The previously published DIRAC experimental result on the observation of long-lived $\pi^+\pi^-$ atoms was used for the first measurement of the long-lived $\pi^+\pi^-$ atom lifetime. All data were analyzed using two approaches taking in to account the atoms production and movement in Be target, propagation in the gap between target and Pt foil and their breakup in the foil. In approach 1 for the analysis were used the total cross sections and the cross sections of atom excitation/deexitation in Be and Pt. In the second approach, in addition the cross sections of atom breakup/ionization were used. The values of the atom shortest lifetime of $2p$ state in the approach 1 and 2 are $\tau_{2p} = 0.45^{+1.08}_{-0.30}\big|_{\text{tot}} \cdot 10^{-11}\text{s}$ and $\tau_{2p} = 0.22^{+1.42}_{-0.18}\big|_{\text{tot}} \cdot 10^{-11}\text{s}$ respectively. These experimental values are in agreement with the same lifetime calculated in QED $\tau_{2p} = 1.17 \cdot 10^{-11}\text{s}$ and on the three order of magnitude more than the measured by DIRAC lifetime of the short-lived atom in the ground state $\tau_{1s} = 3.15^{+0.28}_{-0.26}\big|_{\text{tot}} \cdot 10^{-15}\text{s}$. The performed analyses proved that about 90% of the long-lived atoms have decay length in lab. system from 40 cm up to 140 cm. It open the possibility to measure the atom Lamb shift and to evaluate the combination of the $\pi\pi$ scattering lengths $2a_0 + a_2$. These scattering lengths have been calculated in Lattice QCD and in Chiral Perturbation Theory.

The results on the long-lived atom lifetime measurement published as CERN preprint and it will be submitted to a journal in October 2018.

II. Status of $K^+\pi^-$ and $K^-\pi^+$ atoms investigation.

The paper "**Measurement of the πK atom lifetime and the πK scattering length"** published as a CERN preprint (CERN-EP-2017-137) and Phys. Rev. D96 (2017) 052002

III. K^+K^- pair analysis.

In 2018 the investigation of all experimental data on K^+K^- pairs was performed with an improved procedure of the particles identification using time-of-flight technique and the data from heavy gas Cherenkov counters. The K^+K^- pairs number and systematical error were evaluated in 3 groups which have the background of $\pi^+\pi^-$and proton-antiproton pairs a t level of 30%, 50% and 70% from the total experimental statistics. In each group the K^+K^- pairs distributions of Q, the relative momentum in their c.m., and its projections Q_L, Q_T were analyzed proposing point-like pairs production mechanism. The obtained results will be presented.

These analysis allows to evaluate for the first time the number of K^+K^- atoms generated simultaneously with detected K^+K^- pairs. The dedicated paper will be published before June 2019.

Yields of K^+K^- pairs and of K^+K^- atoms and their distributions have been calculated within FRITIOF generator tuned for required momentum of projectile proton 24 and 450 GeV/c. The dedicated paper will be published before June 2019.

IV. Proton-antiproton pair analysis

The proton- antiproton pairs will be studied with the same strategy as in the K^+K^- case (see section III)

In 2018 DIRAC reprocessed the 2010 RUN experimental data with aim to extract a signal from proton-antiproton pairs and measure their distribution on the momentum in lab. system and the same distributions of background consisting of $\pi^+\pi^-$, K^+K^- and other pairs. These distributions will be shown in the annual report. Study of the distributions of proton-antiproton Coulomb pairs on the relative momentum Q will be completed up to October 2019. It will show a possibility to evaluate the number of relativist proton-antiproton atoms generated simultaneously with the proton-antiproton pairs.

V. Coulomb correlations as a possible new physical method to investigate a size of particles production region in the coordinate space.

The shape of Coulomb correlation curve for K^+K^- and proton-antiproton pairs is expected to be much sensitive to size of particle production region compared to the case of $\pi^+\pi^-$ pairs. Thus, detailed study of this shape could open a possibility to evaluate the size of production region for such pairs. The first experimental distributions of K^+K^- pairs on Q will be shown. The distributions presents an effect which can be qualitative interpret by non point-like production mechanism.

VI. The short-lived $\pi^+\pi^-$ atom lifetime measurement.

Previously, the $\pi^+\pi^-$ pairs from 2008-2010 data were used as a calibration process for the πK pairs analysis. The measurements of short-lived atom lifetime and $\pi\pi$ scattering lengths based on all available 2008-2010 data will be finished in 2019.

VII. High precision investigation of the multiple scattering in Be, Ti, Ni and Pt.

The multiple scattering was measured for a set of foils: Be 100 and 2000 microns; Ti 250 microns; Ni 50, 109 and 150 microns and Pt 2 and 30 microns. The achieved precision of multiple scattering measurement is better than the previous experiments by one order of magnitude. In 2019 this investigation will be completed that allows one to get more precise evaluation of the Moliere theory.