**DIRAC collaboration status report
to SPSC, October 2019.**

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**I. Long-lived states of π+π− atoms.**

The previously published DIRAC experimental result on the observation of long-lived π+π−atoms was used for the first measurement of the long-lived π+π− atom lifetime. The value of the atom shortest lifetime of 2*p* state is $τ\_{2p}=0.\left.45\_{-0.30}^{+1.08}\right|\_{tot}∙10^{-11}s$ . This experimental value is in agreement with the same lifetime calculated in QED $τ\_{2p(QED)}=1.17∙10^{-11}s$ and of three order of magnitude larger than the lifetime of the short-lived atom in the ground state $τ\_{1s}=\left.3.15\_{-0.26}^{+0.28}\right|\_{tot}∙10^{-15}s measured by DIRAC $.

The performed analyses proved that about 30% of the long-lived atoms have decay length in lab. system larger than 40 cm. This opens a possibility to measure the atom Lamb shift and to evaluate the combination of the ππ scattering lengths $ 2a\_{0}+a\_{2}$. These scattering lengths have been calculated with high precision in a set of theoretical papers using Lattice QCD and the Chiral Perturbation Theory.

The long-lived atom lifetime measurement published as CERN preprint in 2018 and in Phys. Rev. Letters 122, 082003(2019).

In the published analysis, the influence of the magnetic field has been estimated in a simplified way that assumed a small shorten of the 2*p* and 3*p* state lifetimes and a full decay of all *np* states with *n*>3 in the gap. In this extreme case, the value of the 2*p* lifetime was evaluated as $τ\_{2p}=0.\left.60\_{-0.30}^{+1.34}\right|\_{tot}∙10^{-11}s $. Now the dependence of the long-lived atoms lifetime from the magnetic field has been calculated for arbitrary *n*. It confirmed that all *np* states with *n*>3 decay in the gap.

**II. *K+K−*** **pair analysis.**

In 2019, the investigation of all experimental data of *K*+*K*– pairs was finished with an improved procedure of the particles identification using time-of-flight technique and the data from the heavy gas Cherenkov counters. The *K*+*K*– pair numbers were evaluated with statistical errors in 3 groups. In each group the *K*+*K*– pair numbers were 30%, 50% and 70% from the total experimental statistics in the group. There is a strong enhancement in the production rate of *K*+*K*– pairs due to the Coulomb interaction in the final state in the range of the pair with the relative momentum in their c.m.s. *Q* less than 10 MeV/c. This effect is strong for *K*+*K*– pairs and weak for background pairs misidentified as *K*+*K*–. To enlarge the reliability of *K*+*K*– pairs evaluation, in each group the distributions were fitted by simulated distributions of *K*+*K*– and background pairs. The final numbers of *K*+*K*– obtained for each group from the analysis of *QL* distributions with cut *QT <* 6 MeV/c are:

 3280±320 (70%), 4580±510 (50%) and 8720±910 (30%).

The same values were evaluated from the analysis in *Q*.

The pairs distributions were used to search for the influence of the non-point pair production region on the Coulomb correlation strength and effects of *K*+*K*– pairs scattering in the final state.

The coefficients which allow to evaluate the total number of produced *K*+*K*– pairs were defined from the experiment thus the total numbers of *K*+*K*– pairs were calculated using pair numbers in each group. The analysis of experimental distribution on *Q* was performed to evaluate for the first time the number of *K*+*K*– atoms generated simultaneously with detected *K*+*K*– pairs.

The draft of dedicated CERN preprint is practically ready and will be sent to the collaboration in November 2019.

**III. The short-lived π+π− atom lifetime measurement.**

Previously, the π+π− pairs from 2008-2010 data were used as a calibration process for the *πK* and *K*+*K*– pairs analysis. We expected to double statistics of π+π− pairs compared to the previously published result.

The measurements of short-lived atom lifetime and ππ scattering lengths based on all available data will be finished in 2020.

**IV. Proton-antiproton pairs analysis**

The total number of detected proton-antiproton pairs with the cut on relative momentum $Q\_{T} <6$ MeV/*c* is estimated as 6900±120. Further study of distributions of these pairs in the pair relative momentum *Q* will allow to evaluate for first time the number of relativistic proton-antiproton atoms generated simultaneously with the detected proton-antiproton pairs. The shape of Coulomb correlation curve for proton-antiproton pairs is expected to be more sensitive to the size of the particle production region compared to the case of detected *K*+*K*– pairs. Thus, detailed study of this shape could open a possibility to evaluate the size of production region of $p\overbar{p}$ pairs.

The data analysis will be finished and the dedicated preprint will be ready before October 2020.

**V. 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 precision achieved of multiple scattering measurement is better than the previous experiments by one order of magnitude.

In 2020 this investigation will be completed to allow one to get more precise checks of the Moliere theory of the multiple scattering.