

DIRAC collaborations status report

October 2016

I. Long-lived states of $\pi^+\pi^-$ atoms.

1. The published DIRAC experimental result on observation of 436 ± 61 long-lived $\pi^+\pi^-$ atoms will be used for measurement of the long-lived $\pi^+\pi^-$ atom lifetime. The corresponding publication is planned for the beginning of 2017.
2. A possibility of evaluation of limit for the $\pi^+\pi^-$ atom Lamb shift, using existing data, will be studied in 2017.

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

1. The paper “Observation of $K^+\pi^-$ and $K^-\pi^+$ atoms” was published in Physical Review Letter 117, 112001(2016) (see also CERN preprint CERN-EP-2016-128; arXiv:1605.06103).
2. From analysis of all available data the $K\pi$ atom lifetime and $K\pi$ scattering length combination $a_0^- = \frac{1}{3}(a_{1/2} - a_{3/2})$ were evaluated:

- One-dimensional analysis over Q : $a_0^- = 0.072_{-0.020}^{+0.031}$, the average relative error is 35%.
- Two-dimensional analysis over Q_L, Q_T : $a_0^- = 0.086_{-0.024}^{+0.044}$, the average relative error is 40%.

The previous published result of DIRAC (Physics Letters B 735 (2014) 288) provided the average relative error equal 60%(analysis on Q_L, Q_T): $a_0^- = 0.11_{-0.04}^{+0.09}$.

The a_0^- values evaluated in LQCD (5% precision), ChPT (about 10% precision) and with Roy-Steiner equations (6% precision) are in agreement with above values.

The dedicated paper will be published before the end of 2016.

III. $\pi^+\pi^-$ atom lifetime measurement.

1. At present time the $\pi^+\pi^-$ pairs are using as calibration process for the πK pairs analysis. Preliminary results on the $\pi^+\pi^-$ atom lifetime measurement based on all available data will be ready in the beginning of 2017 and dedicated paper will be published before the end of 2017.

2. The current value of systematical error in the $\pi^+\pi^-$ atom lifetime measurement is equal to statistical uncertainty. The main part of systematical error arises due to an uncertainty in the multiple scattering in the Ni target. To reduce this error, we continue experimental study of the multiple scattering of our targets: Ni: 50, 109 and 150 microns; Be: 100 and 2000 microns; Pt: 2 and 30 microns and Ti: 250 microns. For Be (2000 microns) and Ni (109 microns) the difference between theoretical and experimental r.m.s. is 0.4% and 0.8% accordingly. The r.m.s. values were calculated in the interval of $\pm 2\sigma$. The achieved precision of multiple scattering investigation is better on one order of magnitude than in the previous experiments. The dedicated paper will be published in 2018.



IV. K^+K^- pair analysis.

1. Search for K^+K^- Coulomb pairs in the existing data will be performed in 2016 with improved procedure of the particles identification using time-of-flight technique. The number of produced K^+K^- atoms can be evaluated from the number of K^+K^- Coulomb pairs. During the first part of the work, K^+K^- pairs with a total momentum in the laboratory system between 2.8 GeV/c and 6.0 GeV/c will be analysed. In this momentum range identification of K^+K^- pairs is more simple. If we will see a signal from the Coulomb pairs, then we will continue to the higher momentum region 6.0 - 9.6 GeV/c.
2. Simulation of K^+K^- pairs and of K^+K^- atoms for proton momentum 24 GeV/c and 450 GeV/c using CERN version of FRITIOF generator is finished
3. Investigation results together with proton-antiproton pairs analysis will be published in the beginning of 2018.

V. Proton-antiproton pair analysis

DIRAC will perform in 2016 a search for proton-antiproton Coulomb pairs and thus proton-antiproton atoms with the same strategy as in the K^+K^- case (see section IV).

VI. Investigation of $K^+\pi^-$, $K^-\pi^+$ and $\pi^+\pi^-$ atoms production in p-nucleus interaction at proton momentum 24 GeV/c and 450 GeV/c

1. The paper "The estimation of production rates of $K^+\pi^-$, $K^-\pi^+$ and $\pi^+\pi^-$ atoms in proton-nucleus Interactions at 450 GeV/c" published in the J.Phys. G: Nucl. Phys. 43 (2016) 095004.

The dedicated analysis has shown that, taking into account the yields of dimesoatoms at 450 GeV/c ($\theta_{lab} = 4^\circ$) and the working conditions at SPS, the number of $\pi^+\pi^-$, $K^+\pi^-$ and $K^-\pi^+$ atoms generated per time unit will be 12 ± 2 , 53 ± 11 and 24 ± 5 times higher than in the DIRAC experiment. The significant increase in the $K^+\pi^-$ and $K^-\pi^+$ atoms statistics will allow to measure $|a_{1/2} - a_{3/2}|$ with precision of 5% and to check our understanding of the chiral $SU(3)_L * SU(3)_R$ symmetry breaking of QCD. The setup upgrade and geometry modification will allow to improve this precision significantly.

In the DIRAC experiment there were observed $436 \pm 57_{stat} \pm 23_{syst}$ long-lived $\pi^+\pi^-$ atoms with the lifetime $\tau \geq 1 \times 10^{-11}$ s. The higher energy of proton beam and the simple change of the experiment scheme open a new possibility for the investigation of the long-lived $\pi^+\pi^-$ atoms. In the new scheme the number of $\pi^+\pi^-$ atoms, generated per time unit will be more than 12 times higher than in DIRAC experiment. The background will be also significantly decreased. The statistics increasing and significant background suppression open a possibility to use the resonance method for measurement of only one parameter, the Lamb shift, and to evaluate the combination of the $\pi\pi$ scattering lengths $2a_0 + a_2$. This measurement uses only the Lorentz transformation and quantum mechanics.

VII. Preparation of a Letter of Intent and report at the workshop “Physics Beyond Colliders” about the investigation of dimesoatoms at SPS energy.

Letter of Intent will be prepared and submitted in April 2017.

The report about the investigation of dimesoatoms at SPS energy was presented at the workshop “Physics Beyond Colliders”.

VIII. Instrumental publication

The paper “Updated DIRAC spectrometer at CERN PS for the investigation of $\pi\pi$ and $K\pi$ atoms” was submitted to NIM, and approved for publication.

IX. Measurement of $K^+\pi^-$, $K^-\pi^+$ and $\pi^+\pi^-$ atoms production cross sections in proton interaction with Be, Ni and Pt nuclei basing of 2007-2012 experimental data will be done in 2018.

Dedicated measurements of the proton flux and the dead time in electronics and DAQ were done for these purposes. Estimation of systematic biases in our cross sections can be done basing on extrapolation of single particle production cross sections available for 32 GeV/c protons. The dedicated paper will be published in 2018.

X. $\pi^+\mu^-$ and $\pi^-\mu^+$ pair analysis

The 2010 experimental data was searched for $\pi^+\mu^-$ and $\pi^-\mu^+$ Coulomb pairs with the aim of extracting the number of $\pi\mu$ atoms produced simultaneously with the Coulomb pairs. An upper limit of the atom production will be calculated and published as DIRAC note before the end of 2017.