DIRAC collaboration status report

April 2017

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 the first measurement of the long-lived $\pi^+\pi^-$ atom lifetime. All data are reprocessed using improved setup geometry, detector response and two types of analysis. The corresponding publication is planned before July 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 $a_0^- = \frac{1}{3}(a_{1/3} - a_{2/3})$ were evaluated:

- One-dimensional analysis over Q: $a_0^- = 0.072^{+0.031}_{-0.020}$, the average relative error is 35%.
- Two-dimensional analysis over Q_L, Q_T : $a_0^- = 0.086^{+0.044}_{-0.024}$, 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): $a_0^- = 0.11^{+0.09}_{-0.04}$.

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 as CERN preprint before June of 2017.
The first draft of the paper (28 pages) is practically ready and will be send to the collaboration in 10 days.

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

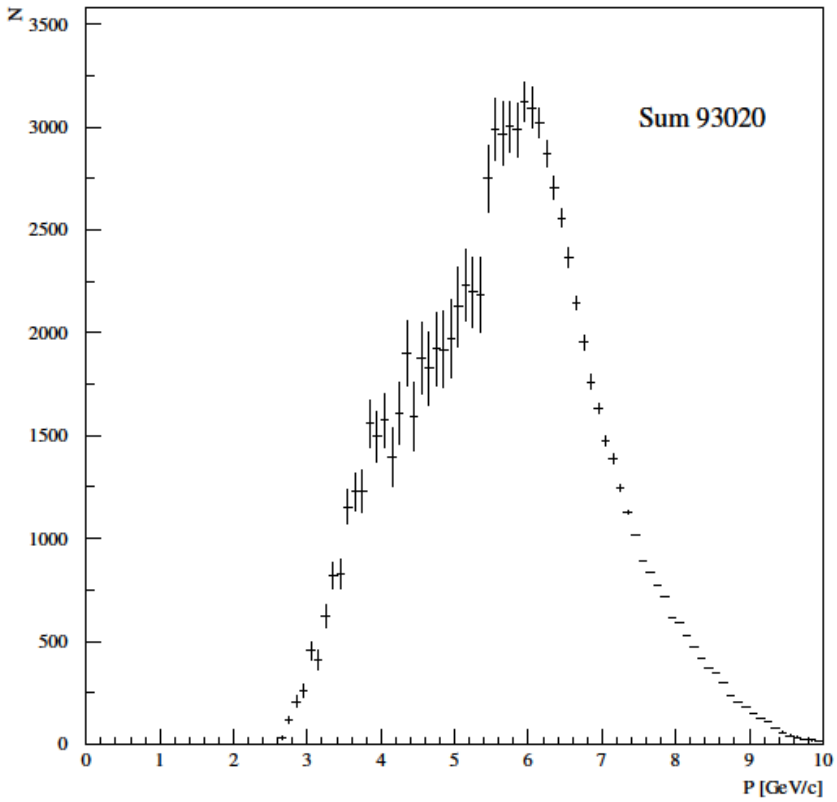
1. At present time the $\pi^+\pi^-$ pairs are using as calibration process for the πK pairs analysis. Preliminary results on the $\pi^+\pi^-$ atom lifetime measurement based on all available data 2008-2010 will be ready in October 2017. In the improved data analysis the new measurement of multiple scattering will be include. The 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 ±2σ. 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 2017 with improved procedure of the particles identification using time-of-flight technique and the data from heavy gas Cherenkov counters. The first step is a search for a signal from the K^+K^- Coulomb pairs. If the signal will be observed than the number of produced K^+K^- atoms can be evaluated from the number of K^+K^- Coulomb pairs with the small relative momentum in their center of mass system. At present time was processed RUN 2010 and after background subtraction was evaluated spectrum of K^+K^- pairs as a function of the pair total momentum in the laboratory system (see figure).



The number of K^+K^- pairs in the RUN 2010 is 90000. The expected total number of K^+K^- pairs is around 230000. After introduction of criteria on the relative momentum components the expected number of pairs will be 45000-70000.

2. Simulation of K^+K^- atoms yield and spectrum for proton momentum 24 GeV/c and 450 GeV/c using CERN version of FRITIOF generator is finished:

DIRAC-NOTE-2016-07 “The estimation of production rates of K^+K^- and proton-antiproton atoms in proton-nucleus interactions at 450 GeV/c”, O. Gortchakov [JINR], L. Nemenov [JINR].

3. Investigation results will be published in the beginning of 2018.

V. Proton-antiproton pair analysis

In 2017 DIRAC will perform 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).
Investigation results will be published in 2018.

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

The paper "The estimation of production rates of $K^+\pi^-$, $K^-\pi^+$ and $\pi^+\pi^-$ atoms in proton-nucleus Interactions at 450GeV/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 ($\theta_{lab} = 4°$) 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 $|a_{1/3} - a_{2/3}|$ with precision of 5% and to check our understanding of the chiral $SU(3)_L \times SU(3)_R$ 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 Lorenz transformation and quantum mechanics.

VII. Preparation of a Letter of Intent and the activity in PBC Committee.

The report about the investigation of dimesoatoms at SPS energy was presented at the workshop "Physics Beyond Collaiders" in September 2016 and the work with PBC Commettee is continuing during 2017: the dedicated reports were presented on the Beam Working Group in February 2017 and on the QCD working group in March 2017. The one of the main requirement of the Beam Working Group is decreasing of the future setup width up to 6 meters. At present time, we are studying two possible setup schemes. In the first scheme detectors with the high coordinate precision and a weaker magnetic field is considered. In the second scheme, usage of two magnet placed one by one is considered. The first magnet will deflect particles and the second one will return them back forming the beam of secondary particles with the small divergence in horizontal plane. The results of thies investigations will be ready in October 2017.

VIII. Instrumental publication

The paper "Updated DIRAC spectrometer at CERN PS for the investigation of $\pi\pi$ and $K\pi$ atoms" was published: Nucl. Instr. Meth. A839 (2016) 52.

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.