**DIRAC status report / April 2016**

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

1. The published DIRAC experimental data on the long-lived π+π**−** atoms observation (the atomic pairs number *n*A=436±61)will be used for the long-lived π+π**−** atoms lifetime measurement. The dedicated publication will be in the beginning of 2017.
2. A possibility of evaluation of limit for the π+π**−** atom Lamb shift, using existing data, will be studied in 2016.

**II. Status of *K*+π− and *K*−π+ atom investigation**

1. The systematic errors were calculated. The second draft of the paper “**Observation of**  ***K*+π− and *K*−π+ atoms”** sent to the collaboration and the paper will be published in the first part of 2016.
2. From this data analysis obtained the ***K*π** atom lifetime and ***K*π** scattering length values. The dedicated paper with detailed description of the analysis procedure will be published in the second part of 2016.

**III. The π+π− atom lifetime measurement**

1. At present time the π+π− pairs are using as calibration process for the π*K* pairs analysis. Preliminary results on the π+π− 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 systematical error in the π+π**−** atom lifetime measurement is equal to statistical uncertainty. The main part of systematical error arise due to 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 ±2σ. The achieved precision of multiple scattering investigation on the order of magnitude better than in the previous experiments. The dedicated paper will be published in 2017.

**IV. *K*+*K*− pair analysis**

1. The 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 extracted 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 analyzed. 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 in progress.
3. This investigation results together with proton-antiproton pairs analysis will be published in 2017 or 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*+π–, *K*–π+ and π+π– atoms production in p-nucleus interaction at proton momentum 24 GeV/c and 450 GeV/c**

The paper “**The estimation of production rates of *K*+π–, *K*–π+ and π+π– atoms in proton-nucleus interactions at 450 GeV/c”** submitted to the J.Phys.G: Nucl. Phys. The minimum values of the yields ratio of *K+π−,* *K−π+* and *π+π−* atoms in p-nucleus interactions at proton momenta of 24 and 450 GeV/*c* are given in the table 1. The best ratio between the dimesoatoms number and the secondary’s charge particles flax in the same solid angle will be at emission angle *θlab* = 4°.

The beam time during super cycle on SPS on factor 5 more than on the PS. It gives additional increasing for the atom production per time unity.

For the long-lived atoms investigation one can used the new scheme of experiment allowing to increase the number of produced dimesoatoms per unity time more than on two orders. In this scheme, the background of Coulomb and non-Coulomb pairs will be decreased more than on the order of magnitude relative background in the DIRAC experiment scheme. The possibility of the new scheme of experiment on SPS will be studied in 2016 together with a possibility to use the resonance method, which allows to measure the energy levels splitting in *π+π−* atom and the new combination of *ππ* scattering length. In this method for the experimental data analysis are using only quantum mechanics and Lorenz transformation.

Table 1: Minimum yield ratios for *π*+*π*−, *π*+*K*− and *K*+*π*− atoms, *WA*, into the aperture of 10−3 *sr*, taking into account the setup acceptance and pion and kaon decays per one p-Ni interaction at the proton momenta *P*p= 24 and 450 GeV/c for different emission angles *θlab*. The correlation function *R*24GeV*/c* is set equal to R450GeV/*c*. We have fixed the yields at 24 GeV/c (PS) as reference.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| *θlab* | 5*.*7° | 4° | 2° | 0° |
| *E*p | 24 GeV/c | 450 GeV/c | 450 GeV/c | 450 GeV |
|  |  | yield of *π*+ | *π*− atoms |  |
| *WA* | 1 | 9*.*7 ± 1*.*5 | 17*.*5 ± 2*.*8 | 22*.*7 ± 3*.*6 |
|  |  | yield of *π*+ | *K*− atoms |  |
| *WA* | 1 | 45 ± 8 | 87 ± 15 | 104 ± 18 |
| yield of *K*+ *π*− atoms | | | | |
| *WA* | 1 | 18*.*6 ± 4*.*1 | 41 ± 9 | 52 ± 11 |

**VII. Preparation of a Letter of Intent about the investigation of hadronic atoms at SPS energy.**

Letter of Intent will be prepared and submitted after investigation of the possibility to increase significantly the yields of dimesoatoms per time unit and background suppression. The planning time for the submission is October 2016.

1. **Instrumental publication**

The paper “Updated DIRAC spectrometer at CERN PS for the investigation of *ππ* and *Kπ* atoms” has been submitted to NIM. At present time the paper is updating in accordance with the referee comments.

**IX. Measurement of *K*+π−, *K*−π+ and π+π− atoms production cross sections in proton interaction with Be, Ni and Pt nuclei basing of 2007-2012 experimental data will be done in 2017.**

Dedicated measurements of the proton flux and the dead time of electronics and of 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. π+µ− and π−µ+ pair analysis**

The 2010 experimental data has been searched for *π+µ−* and *π−µ*+ Coulomb pairs with the aim of extracting the number of πµ atoms produced simultaneously with the Coulomb pairs. An upper limit on the atom production will be calculated and published as DIRAC note before the end of 2017.