**CERN, October 2015.**

**DIRAC collaboration status report.**

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

1. Paper “First observation of long-lived π+π**−** atoms” accepted for publication in PhysicsLetters B.

The number of atomic pairs from long-lived π+π**−** atom breakup in the Pt foil is:

*n*A=436±57|stat±23|syst=436±61|tot (7.1 σ).

2. The measurement of the long-lived π+π− atom lifetime.

The total number of produced π+π− atoms in the Be target has been evaluated. The number of long-lived π+π− atom at the Be target exit, their distribution on quantum numbers *n, l, m* and the breakup probability in the Pt foil have been calculated. Using the experimental value of broken long-lived π+π**−** atoms *n*A and the known atom momentum distribution will allow to measure the long-lived atom lifetime. A preliminary value of the lifetime will be presented in April 2016.

3. A possibility to evaluate a limit for the π+π**−** atom Lamb shift, using existing data, will be studied in the first part of 2016.

4. The 2011 run data will be used to evaluate the number of π+π**−** atoms and atomic pairs generated on Be target that can improve the above result obtained with 2012 data.

**II. Status of *K*+π− and *K*−π+ data processing.**

1. The Monte-Carlo simulation with the improved SFD response for the runs of 2007, 2008, 2009, 2010 and 2012 is ready. The analysis of the Lambda width using M.C. with the improved SFD response has been performed.

2. The improved procedure of *K*+, π+ and proton identification, using time of flight, is ready and applied to the 2007, 2008, 2009, 2010 and 2012 run data. This procedure enlarges the statistics of *K*π pairs by 30% for the 2008-2010 runs.

3. The procedure to match downstream tracks with SFD hits will be modified accounting for the dependence of the expected hit region on particle momenta. The main aim of this procedure is to improve the quality of the statistics with low and medium background and to process for the first time the part of the statistics with high background (1/3 of the total data).

4. Preliminary results on *K*+π− and *K*−π+ atom investigation, using all the data available from the 2007, 2008, 2009 and 2010 runs and with the improved analysis, will be ready in April 2016.

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

1. At present time the π+π− pairs are used for calibration purposes in the π*K* pair analysis. Preliminary results on the π+π− atom lifetime measurement, based on all available data, will be ready at the end of 2016.

2. The current systematical error in the π+π**−** atom lifetime measurement is equal to the statistical uncertainty. The main part of the systematical error arises from multiple scattering in the Ni target. To reduce this error we continue to investigate multiple scattering in 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.

**IV. *K*+*K*− pair analysis.**

1. The search for *K+K−* Coulomb pairs in the existing data will be performed in 2016 with the improved procedure of particle identification using the 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 region the identification of *K+K−* pairs is simpler. If we see a signal, then we extend the analysis 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 the CERN version of the FRITIOF generator, is in progress.

3. The theoretical investigation of the *K+K−* atom wave functions for S and P states and of the *K+K−* atom lifetime for S and P states needs to be performed.

**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+, π+π–, *K*+*K*– atom production in p-nucleus interaction at proton momenta 24 GeV/c and 450 GeV/c**

A DIRAC note on the simulation of inclusive production of *K+*, *K−*, *π+* and *π−* in p-nucleus interactions at 24 GeV/c and 450 GeV/c has been published. The minimum yields of *K+π−,* *K−π+* and *π+π−* atoms in p-nucleus interactions at proton momenta of 24 GeV/*c* and 450 GeV/*c* are given in table 1.

The beam time during the SPS super cycle is a factor 5 larger than in the PS case, leading to an additional increase of the atom production rate. For the long-lived atom investigation one can use a new experimental scheme allowing to increase the dimesoatom production rate by more than two orders. In this scheme, the background of Coulomb and nonCoulomb pairs will be decreased by more than one order of magnitude, relative to the background in the DIRAC experiment at PS. The new scheme in an experiment at SPS will be studied in 2016 together with the possibility to exploit the resonance method, which allows to measure the energy level splitting in *π+π−* atoms and so a new combination of *ππ* scattering lengths. For the analysis of data obtained by the new method, only quantum mechanics and Lorenz transformation have to be applied.

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

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| *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*.*73 ± 0*.*09)10−9 | (1*.*7 ± 0*.*2) ∙10−8 | (3*.*0 ± 0*.*5) ∙10−8 | (3*.*9 ± 0*.*6) ∙10−8 |
|  | 1 | 9*.*7 ± 1*.*5 | 17*.*5 ± 2*.*8 | 22*.*7 ± 3*.*6 |
|  |  | yield of *π*+ | *K*− atoms |  |
| *WA* | (1*.*46 ±0.09)10−11 | (6*.*6 ± 1*.*1) ∙10−10 | (1*.*31 ± 0*.*21) ∙10−9 | (1*.*52 ± 0*.*24) ∙10−9 |
|  | 1 | 45 ± 8 | 87 ± 15 | 104 ± 18 |
| yield of *K*+ *π*− atoms | | | | |
| *WA* | (4*.*2 ± 0*.*3) ∙10−11 | (7*.*9 ± 1*.*6) ∙10−10 | (1*.*8 ± 0*.*4) ∙10−9 | (2*.*2 ± 0*.*5) ∙10−9 |
|  | 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.**

A Letter of Intent will be prepared and submitted after investigating the possibility to increase significantly the yields of dimesoatoms per time and to suppress background. We plan to submit this letter in 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.

**IX. Measurement of *K*+π−, *K*−π+ and π+π− atom production cross sections in proton interaction with Be, Ni and Pt nuclei, based on 2007-2012 data, to be done in 2017.**

Dedicated measurements of proton flux and electronics and DAQ dead time have been done. Systematic biases in our measured cross sections can be estimated by extrapolating the single particle production cross sections, which are available for 32 GeV/c protons.

**X. π+µ− and π−µ+ pair analysis**

In the 2010 experimental data DIRAC has searched for *π+µ−* and *π−µ*+ Coulomb pairs. The aim is to extract the number of πµ atoms, produced in parallel with corresponding Coulomb pairs. An upper limit on the atom production will be deduced and published as DIRAC note before the end of 2017.