CERN, October 2014

DIRAC collaboration status report 2014

I. π^+K^- and π^-K^+ atom

1. Published paper: First **πK** atom lifetime and **πK** scattering length measurements, *Physics Letters B* 735 (2014) 288

   In this paper characteristic πK pairs from πK atom breakup in the Ni target have been observed, as many as

   178±49 (3.6σ) πK atomic pairs as well as

   653±42 produced πK atoms.

   Based on these results, the first measurement of the πK atom lifetime has been deduced:

   $$\tau = \left(2.5^{+3.0}_{-1.8}\right) fs$$

   and the first measurement of the S-wave isospin-odd πK scattering length:

   $$\left|a_0^-\right| = \frac{1}{3}\left|a_{1/2} - a_{3/2}\right| = \left(0.11^{+0.09}_{-0.04}\right) M_\pi^{-1}$$

   The result was obtained using 2/3 of the existing statistics with low and medium background in the scintillation fiber detector.

2. The procedure to process and analyse $K^-\pi^+$ and $K^+\pi^-$ pairs with high background (in the remaining 1/3 of total statistics) has been developed using large statistics of $\pi^+\pi^-$ pairs. The same analysis will be used for $K\pi$-atoms because the multiplicity in all detectors is the same for $\pi\pi$ and $K\pi$ triggers.

   To enlarge the $K\pi$ atomic pair statistics, the 2007 $K^-\pi^+$ and $K^+\pi^-$ atom data, collected on *Pt* target, will be reprocessed using Monte Carlo background description, two dimensional analysis and better software setup tuning. The significance of the expected number of atomic pairs measured in 2007 and 2009-2010 runs will be around 5 standard deviations. This work and the dedicated publication will be finished in October 2015.

II. Long-lived $\pi^+\pi^-$ atom

1. The results of the data with low and medium background (2/3 of existing data) are presented in the **Table 1**. The experimental distributions of events on Q_L were analysed at 3 values of Q_T cuts (column 1), where Q_L (Q_T) is the longitudinal (transversal) component of the relative momentum Q in the $\pi\pi$ c.m.s. In this analysis the distributions are fitted with a sum of Coulomb and non-Coulomb pairs generated in the *Be* target and atomic pairs originating from the breakup of long-lived atoms in the *Pt* foil placed at 100mm distance from the *Be* target. The numbers of detected atomic pairs as well as total atomic pairs are shown in columns 2 and 4. The last column presents the sum of the Coulomb and non-Coulomb pairs (background) in the signal region: $Q_L < 1.5$MeV/c.

Table 1

Q_T^{cut}	n_A	Selection efficiency	n_A^{tot}	Background for $Q_L \leq 1.5$ MeV/c
$Q_T < 0.5$ MeV/c	159±27 (~5.9σ)	0.365	436±74	690
$Q_T < 1.0$ MeV/c	415±53 (~7.8σ)	0.795	522±67	2775
$Q_T < 1.5$ MeV/c	433±78 (~5.5σ)	0.945	458±83	6360

The DIRAC Collaboration aims to finish this analysis and to publish a corresponding paper "*First observation of the long-lived $\pi^+\pi^-$ atoms*" in February 2015.

2. In 2015, we will study the possibility to process and to analyse ππ pairs with high background (in the remaining 1/3 of the total statistics) and further to evaluate a lower limit for the Lamb shift based on the existing data.
3. In 2015 we intend to process 2011 data.

III. **$\pi^+\pi^-$ atom analysis**

1. The $\pi^+\pi^-$ atom data analysis will be finished in 2015 using statistics with low, medium and high background (about 30000 atomic pairs).
   The evaluated atom lifetime will be submitted before July 2016.
2. The measurement of multiple scattering in *Be*, *Ni* and *Pt* targets with about 0.5% accuracy will be accomplished and published before July 2016.

IV. **K^+K^- pair analysis**

A search for K^+K^- Coulomb pairs in the existing data will be performed, and the number of K^+K^- atoms, produced simultaneously with these Coulomb pairs, will be extracted. In the first part of the work until July 2015, we will analyse K^+K^- pairs with a total momentum in the laboratory system (l.s.) from 2.8 GeV/c up to 6.0 GeV/c.

By occurrence of a signal, Coulomb pairs will also be searched for in the higher momentum region from 6.0 GeV/c up to 9.6 GeV/c.

V. **Proton–antiproton pair analysis**

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). The search for the proton–antiproton Coulomb pairs in the lower momentum region will be finished before May 2016.

VI. **$\pi^+\mu^-$ and $\pi^-\mu^+$ pair analysis**

Analogously the 2010 experimental data will be investigated with respect to $\pi^+\mu^-$ and $\pi^-\mu^+$ Coulomb pairs aiming to extract the number of πμ atoms, produced simultaneously with these Coulomb pairs. The analysis will be finished in January 2015. By presence of a signal the 2011 and 2012 data will be processed in order to improve statistics.

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

A DIRAC note will be presented in January 2015 on the simulation of the inclusive production of K^+, K^-, π^+ and π^- in p-nucleus interaction at 24GeV/c and 450GeV/c, to be compared with dedicated experimental data. The yield of $K^+\pi^-$, $K^-\pi^+$ and $\pi^+\pi^-$ atoms in p-nucleus interaction at proton momenta 24 and 450GeV/c will then be calculated.

VIII. **Preparation of a Letter of Intent about the investigation of dimesoatoms at SPS energy before November 2015**

IX. **$\mu^+\mu^-$ pair analysis**

Monte-Carlo simulations will be used to study - before end 2015 - the possibility to observe $\mu^+\mu^-$ Coulomb pairs. If the calculated results are promising DIRAC will analyse the existing experimental data (2001-2003 and 2007-2012) to search for $\mu^+\mu^-$ Coulomb pairs. These pairs allow to evaluate the number of $\mu^+\mu^-$ atoms, produced simultaneously with Coulomb pairs.

X. **Use of experimental data 2007-2012 to measure production cross-sections for $K^+\pi^-$, $K^-\pi^+$ and $\pi^+\pi^-$ atoms in proton interaction with Be, Ni and Pt nuclei in 2016**

XI. **Instrumental publication**

DIRAC intends to submit a paper "Updated DIRAC spectrometer at CERN PS for the investigation of ππ and Kπ atoms" before the end of the year 2014. This paper covers all the details of the detectors and discusses the overall performance of the spectrometer.