

DIRAC status report June 2016

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

1. The published DIRAC experimental data on the long-lived $\pi^+\pi^-$ atom observation (atomic pair number $n_A=436\pm 61$) will be used for the long-lived $\pi^+\pi^-$ atom lifetime measurement. **The dedicated paper will be published in the beginning of 2017.**
2. A possible evaluation of a limit for the $\pi^+\pi^-$ atom Lamb shift, using existing data, will be studied in 2017.

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

1. The paper “**Observation of $K^+\pi^-$ and $K^-\pi^+$ atoms**” has been “published” as preprint (CERN-EP-2016-128; arXiv:1605.06103) and submitted to PRL. Below the editor’s response is presented:

From: Kevin Dusling [kdusling@aps.org]
Sent: 30 May 2016 05:39
To: Juerg Schacher
Subject: Re: arXiv:1605.06103

Great news. I will send it out to review shortly and contact you once we have reports in.

Best Regards,
Kevin

2. Using all available data, the analysis yields values for the $K\pi$ atom lifetime and $K\pi$ scattering length combination $|a_0| = 1/3 |a_{1/2} - a_{3/2}|$:

- Analysis on Q: $|a_0| = 0.072 - 0.020 + 0.031$, average relative error: 36%

- Analysis on (QL,QT): $|a_0| = 0.086 - 0.024 + 0.044$, average relative error: 40%

Published result (PLB, 2014) from (QL,QT) analysis:

$|a_0| = 0.11 - 0.04 + 0.09$, average relative error: 60%

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

$a_0 = 0.09$ with the relative error 6% (Roy-Steiner equation).

The dedicated paper will be published before November 2016.

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

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

2. The current systematical error in the $\pi^+\pi^-$ atom lifetime measurement is equal to the statistical uncertainty. The main part of systematical error arises due to multiple scattering in the Ni target. To reduce this error, we continue the experimental study of multiple scattering in our targets: Ni: 50, 109 and 150 microns; Be: 100 and 2000 microns; Pt: 2 and 30 microns; 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 $\pm 2\sigma$. The achieved precision of the multiple scattering investigation is an 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 the improved procedure of the 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 analysed. In this momentum range, the identification of K^+K^- pairs is simpler. If we will see a Coulomb pair signal, then we will continue the search in the higher momentum region 6.0 - 9.6 GeV/c.

2. The simulation of K^+K^- pairs and K^+K^- atoms for 24 GeV/c and 450 GeV/c protons, using the CERN version of the FRITIOF generator, is in progress.

3. The results together with proton-antiproton pair analysis will be published in the beginning of 2018.

V. Proton-antiproton pair analysis

In 2016, DIRAC will 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 the $K^+\pi^-$, $K^-\pi^+$ and $\pi^+\pi^-$ atom production in the proton-nucleus interaction for 24 GeV/c and 450 GeV/c protons

The paper “The estimation of production rates of $K^+\pi^-$, $K^-\pi^+$ and $\pi^+\pi^-$ atoms in proton-nucleus interactions at 450 GeV/c” has been submitted to the J. Phys. G: Nucl. Phys., and the referee’s comments introduced in the text.

The analysis has shown that - taking into account the yields of dimesoatoms at 450 GeV/c ($\theta_{lab} = 4^\circ$) and the SPS working conditions, the number of $A_{2\pi}$, $A_{\pi^+K^-}$ and $A_{\pi^-K^+}$ 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 $A_{\pi^+K^-}$ and $A_{\pi^-K^+}$ statistics will allow to measure $|a_{1/2} - a_{3/2}|$ with a precision of 5% and to check our understanding of the chiral $SU(3)_L * SU(3)_R$ symmetry breaking of QCD for the first time. The setup upgrade and geometry modification will allow to improve this precision significantly.

In the DIRAC experiment, $436 \pm 57_{stat} \pm 23_{syst}$ long-lived $A_{2\pi}$ atoms with a lifetime of $\tau \geq 1 \times 10^{-11}$ s were observed. The higher energy proton beam and the simple change of the experiment scheme open a new possibility to investigate long-lived $\pi\pi$ atoms. In the new scheme, the number of $A_{2\pi}$, $A_{\pi^+K^-}$ and $A_{\pi^-K^+}$ generated per time unit will be 60 ± 9 , 265 ± 53 and 120 ± 24 times higher than in the DIRAC experiment. The background will be decreased by two orders of magnitude. The increased statistics and the significant background suppression will allow to use the resonance method for measuring only one parameter, the Lamb shift, and to evaluate the combination of the $\pi\pi$ scattering lengths $2a_0 + a_2$. This measurement only uses Lorentz transformation and quantum mechanics.

The possibility to observe K^+K^- atoms is under investigation.

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

The Letter of Intent will be prepared and submitted in October 2016. The abstract will be sent to CERN in June 2016.

VIII. Instrumental publication

The paper “Updated DIRAC spectrometer at CERN PS for the investigation of $\pi\pi$ and $K\pi$ atoms” has been submitted to NIM, updated in accordance with the referee’s comments and sent to NIM for the second time.

IX. The Measurement of $K^+\pi^-$, $K^-\pi^+$ and $\pi^+\pi^-$ atom production cross sections in proton interaction with Be, Ni and Pt nuclei based on the 2007-2012 experimental data will be performed in 2017.

For this purpose, dedicated measurements of the proton flux and of the electronics and DAQ dead time were done. Estimation of systematic biases in our cross section measurements can be done based on extrapolating the 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 has been investigated regarding $\pi^+\mu^-$ and $\pi^-\mu^+$ Coulomb pairs with the aim to extract the number of $\pi\mu$ atoms produced in parallel with Coulomb pairs. An upper atom production limit will be calculated and published as a DIRAC note before the end of 2017.