

Scientific plans of DIRAC collaboration

The main task of the DIRAC experiment is to check precise predictions of low-energy QCD.

1. At present, theory predicts the $\pi\pi$ s -wave scattering lengths with a precision of 1.5-2.5% for a_0 , a_2 , a_0-a_2 . The theoretical uncertainty is mainly due to uncertainties of two constants of ChPT. In 2006 these constants were obtained from Lattice calculation, and we can expect that in a few years this calculation will result in an even higher precision of $\pi\pi$ scattering lengths. Experimentally, the scattering lengths were obtained from K -meson decays ($K_{3\pi}$, K_{e4}) and from the $\pi\pi$ -atom lifetime. At present, the precision of $\pi\pi$ scattering lengths measurements is at the level of 5 to 6%, hence significantly worse than the theoretical precision. For this reason, improving the experimental accuracy is an important task. The DIRAC experiment will take data in 2008 and 2009 to obtain a precision of about 2.5% for $|a_0-a_2|$.

2. Now, theory predicts πK scattering lengths with a precision of about 10% but in near future this accuracy will be significantly improved. Experimentally, the πK scattering lengths were obtained from πK scattering phases at high energy using Roy-Stainer equations. Direct measurements of πK phases at low energy or πK scattering lengths do not exist. The DIRAC experiment will observe πK atoms using data collected in 2007. Data taking in 2008 and 2009 will allow us to measure the lifetime of this atom and to obtain the first evaluation of the scattering length combination $|a_{1/2}-a_{3/2}|$. The measurement of the s -wave πK scattering lengths would test our understanding of the chiral $SU(3)_L \times SU(3)_R$ symmetry breaking of QCD (u , d and s quarks), while the measurement of $\pi\pi$ scattering lengths checks only the $SU(2)_L \times SU(2)_R$ symmetry breaking (u , d quarks).

3. In 2009 we are planning to present an Addendum to the DIRAC experiment with the aim to observe the long-lived states of $\pi\pi$ atoms in 2010. Further data taking in 2011 will allow us to obtain experimentally the Lamb shift ΔE_{2s-2p} in this atom. The measurement of ΔE_{2s-2p} allows determining in a model-independent way the combination of $\pi\pi$ scattering lengths $2a_0+a_2$. Together with the $\pi\pi$ atom lifetime measurement, a_0 and a_2 will then be determined separately. The method of the Lamb shift measurement uses only the well-known theory of the Stark effect and does not have the systematic errors known from the lifetime measurement. This experiment can be performed with the existing setup without change of detectors nor electronics.

4. From the data to be collected in 2008 and 2009 it will be possible to observe the Coulomb enhancement in the production of K^+K^- pairs, and thus to determine, in a model independent way, the number of K^+K^- atoms to be produced at the same time. This analysis will allow to assess the feasibility to observe these atoms and to measure their lifetime.

5. The 2008-2009 data will also allow to search for the Coulomb enhancement in production of $\pi\mu$ pairs, and thus to determine, in a model-independent way, the number of $\pi\mu$ atoms to be produced. This analysis will allow to decide if it is possible

or not to observe this atom. The lifetime of this atom coincides with the lifetime of charged pions, thus its free path is hundreds of meters. Therefore the detection method can be modified; the setup can be supplemented with a cleaning magnet to deflect the secondary charged particles. This allows increasing intensity of the proton beam and achievable statistics significantly. The final aim is to measure the Lamb shift in the $\pi\mu$ atom, which is strictly related to the electromagnetic radius of charged pion.

6. The new possibilities (points 3 to 4) to check the predictions of the low-energy QCD will be available after installation of the DIRAC setup on a 450GeV/c SPS proton beam. Simulations were based on FRITIOF6, which gives correct π and K-meson spectra in the dynamic range of the DIRAC spectrometer. At the same intensity of the secondary particles across the forward detectors the number of detected $\pi\pi$ atoms will be 15 times higher than the one at 24GeV, the number of $K^+\pi^-$ atoms 25 times and the number of $K^-\pi^+$ atoms 32 times higher. This enhancement in atom yields allows to obtain simultaneously $|a_0-a_2|$ with full precision of about 1.5% and $|a_{1/2}-a_{3/2}|$ with statistical precision of 2.5% within 12 months of data taking. The measurement of the Lamb shift in $\pi\pi$ atom with a statistical precision of 2.5% would take another 12 months together with the Lamb shift measurement in πK atom. These results will give the crucial check of low-energy QCD predictions.

Migration from PS to PS2 with the 50 GeV beam will also provide a significant gain in the mesonic atom production. The required statistics and achievable accuracy are under investigation.