6 Search for $K\pi$-atoms

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(DIRAC-II Collaboration)

The $K\pi$-scattering length is of interest to test chiral perturbation predictions involving the s-quark. The low energy $K\pi$-phase shifts (S-wave isospin 1/2 and 3/2 phases) are poorly known below 1 GeV/c and hence their extrapolations to zero energy are very uncertain. We are therefore searching for the electromagnetically bound $K^+\pi^-$ (and $K^-\pi^+$) system to measure its mean life τ which is related to the S-wave $K\pi$-scattering length. We intend to measure τ (predicted to be about 3.7 fs) with a precision of 10%.

Details on the DIRAC apparatus can be found in Ref. (1). We have developed and built the aerogel Čerenkov counters and the heavy gas system required to identify kaons from the dissociation of $K\pi$-atoms, and are responsible for the analysis of the corresponding data. More on these detectors can be found in previous annual reports and in a recent publication (2).

The aerogel detector is located in the left (positive charge) arm of the DIRAC spectrometer and consists of three independent modules. Two of them have aerogel with the refractive index $n = 1.015$ (24ℓ) for kaon-proton separation between 4 and 5.5 GeV/c , and the third one (13ℓ) has the lower index $n = 1.008$ for 5.5 to 8 GeV/c kaons. The loss due to light absorption is compensated by using a wavelength shifter and also by increasing the radiator thickness at the center of the detector (pyramid geometry). A cosmic ray test showed that, thanks to the pyramid design, the light yield did not depend significantly on the impact position. For the 1.015 detector we obtained about 6.4 photoelectrons for cosmic muons, implying ~ 5 photoelectrons for 4 GeV/c kaons. The performance of the 1.008 counter could not be tested with cosmic rays.

Figure 6.1 shows the aerogel counters installed in the DIRAC experiment in the West hall at CERN. The operation of the DIRAC-II experiment, originally planned for summer 2006, was postponed by one year due to repeated failures of a switching magnet in the CERN primary proton beam line. The defective magnet was successfully replaced by CERN in spring 2007 and DIRAC-II could finally be commissioned in June 2007. The aerogel counters worked in the beam according to expectations, although we had first to strengthen

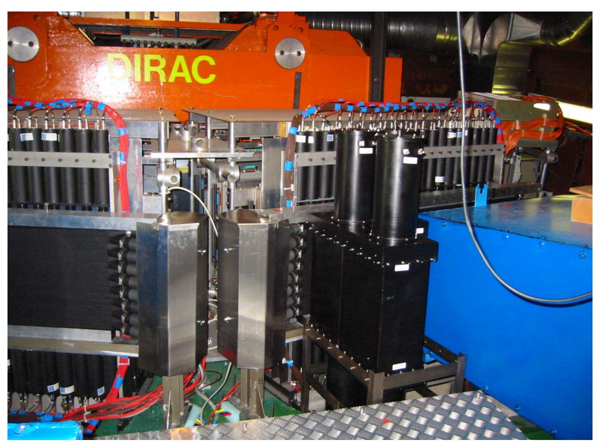

Figure 6.1: Photograph of the three aerogel modules (black) in the experimental area. The scintillation hodoscopes and the N_2-Čerenkov counter (blue) are also visible.

[3] Visitor from the University of Basel

the magnetic shielding of the (vertical) photomultipliers with additional μ-metal to protect them from the fringe field of the DIRAC dipole magnet, which is also vertical.

The trigger rejects electrons with the N_2-Čerenkov detector in anticoincidence and selects symmetric tracks in the two spectrometer arms. Mainly pions and protons are present, as well as a few kaons. The pions are shown by the green ellipse and protons by the red ellipse in Fig. 6.2. The horizontal accumulation of events at low amplitudes (blue ellipse) is due to the ADC pedestals for triggers with protons below Čerenkov threshold, including electronic noise. Kaons are not visible at this point due to their low intensity.

Data were also taken with inverted polarities to study the proton contamination, i.e. by triggering on negative tracks in the aerogel arm, in which case the contribution from antiprotons is negligible. The normalized ADC spectra were then subtracted, leaving essentially protons in the positive charge spectrum which was then subtracted from the distribution shown in Fig. 6.2, leading to a pure K^+-spectrum. Figure 6.3 shows the distribution of the light amplitude which agrees with cosmic ray measurements. The peak at low amplitudes is due to the one-photon contribution. Cutting at one photoelectron one obtains a proton rejection efficiency of about 93.2%, while the kaon detection efficiency is 94.2%. The proton contribution can also be studied with $\Lambda \rightarrow \pi^- p$ decays (see Fig. 6.4).

We have also built the C_4F_{10} heavy gas system for the Čerenkov counters in both arms to veto pions. The counters were delivered by our collaborators from Dubna. The system has been running since June 2007 without interruption. However, the rate of C_4F_{10} loss was found to be larger than initially estimated and be modified. The design of the improved scheme has been done (Fig. 6.5) and the construction will be completed for the 2008 runs.

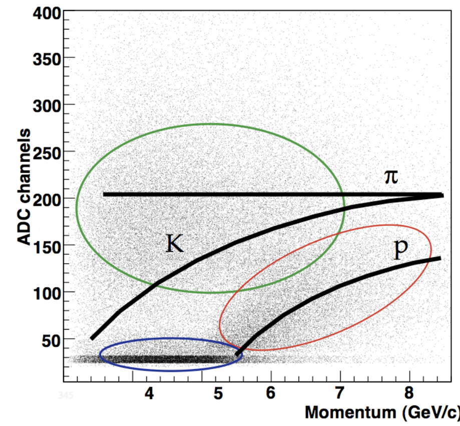

Figure 6.2: Signal amplitude (in ADC counts) as a function of momentum for one of the n=1.015 aerogel modules. The curves show the expected light yields. The ellipses show the pions (green), the protons (red) and the electronics noise (blue).

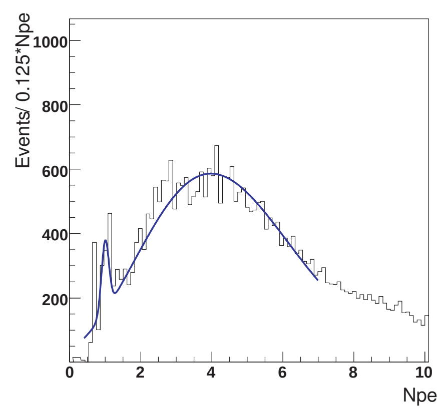

Figure 6.3: Distribution of the light output (in photoelectrons, N_{pe}) for positive kaons traversing the heavy aerogel counter (see text). The curve is a fit.

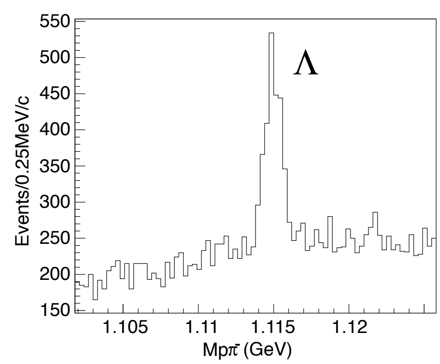

Figure 6.4:
Λ-signal in the $\pi^- p$-invariant mass distribution.

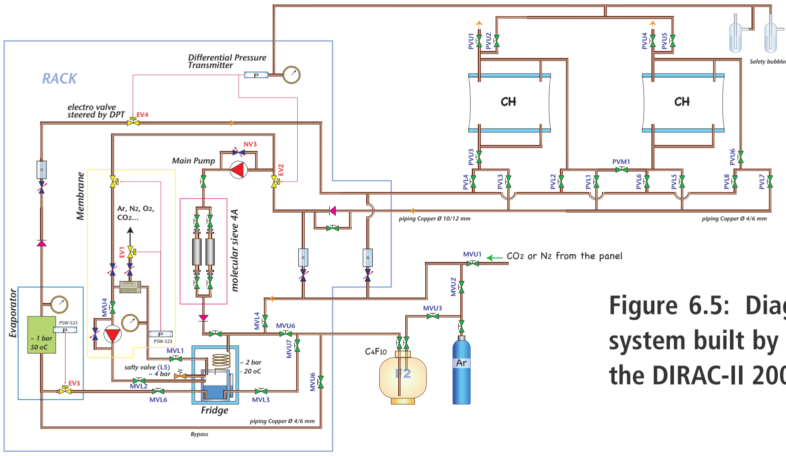

Figure 6.5: Diagram of the radiator-gas recirculation system built by our group (improved in robustness for the DIRAC-II 2008 runs).

Figure 6.6 shows an amplitude spectrum for electrons from the C_4F_{10}-detector, obtained by triggering on the N_2-Čerenkov counter. Dividing the mean amplitude by that of the single-photoelectron peak, we obtain the mean number of photoelectrons $N_{\rm pe} = 28.0 \pm 0.2$.

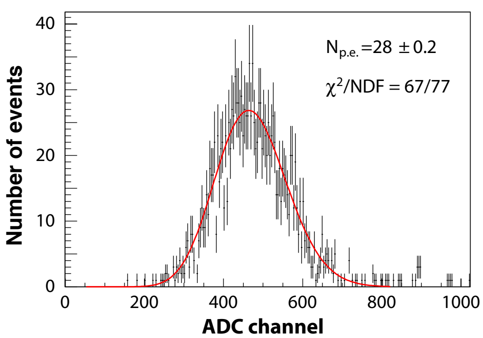

Figure 6.6: Amplitude spectrum of electrons in the heavy gas counter.

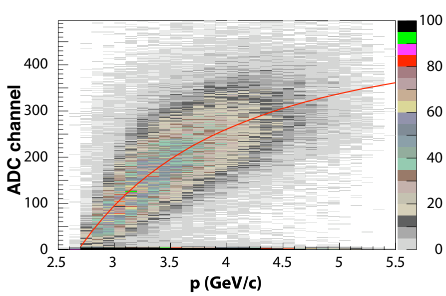

Figure 6.7: Pulse height distribution for pions as a function of momentum.

Figure 6.7 shows the signal amplitude for pions as a function of momentum. The curve is a fit in which the refractive index of the radiator and the number of photoelectrons were set as free parameters, assuming a velocity $\beta = 1$. The fit leads to a refractive index $n = 1.00137$ which corresponds to a wavelength of 300 nm for Čerenkov photons and is consistent with the Čerenkov spectrum convoluted with the spectral response of the UV-glass photomultiplier. The pion detection efficiency is found to be larger than 99.5% at 4 GeV/c.

The yield of $K\pi$- atoms is expected to be about 25 $\times$ lower than for $\pi^+\pi^-$-atoms (3). Assuming equal acceptances and the increase in beam flux between the former DIRAC I experiment (which studied $\pi^+\pi^-$-atoms) and DIRAC II by a factor of two, this should lead to about 1′400 reconstructed $K^+\pi^-$- (and $K^-\pi^+$-) atoms in the 2007 sample. DIRAC II will take data at least until the end of 2009.

[1] B. Adeva *et al.*, Nucl. Instr. and Meth. in Phys. Research **A 515** (2003) 467.

[2] Y. Allkofer *et al.*, Nucl. Instr. Meth. in Phys. Research **A 582** (2007) 497.

[3] B. Adeva *et al.* (DIRAC Collaboration), Phys. Lett. **B 619** (2005) 50.