Additional Justification of the DIRAC beam time Request CERN/SPSC 2002-034

The DIRAC collaboration

The DIRAC experiment aims at measuring $\pi^+\pi^-$ track pairs with momenta above $p_{\pi^+\pi^-} \geq 1.5$ GeV/c, but with relative momentum $Q_{\pi^+\pi^-} \leq 4$ MeV/c. This requires

- high reconstruction quality for very close lying track pairs
- good knowledge of multiple scattering in the target and in the detectors
- knowledge of the normalization (K)-factor, which relates the amount of Coulomb-correlated (CC) background to the number of produced atoms

Substantial systematic uncertainties are encountered in the reconstruction of track pairs, the extraction of background and signal of atomic pairs, as well as in multiple scattering, which turns out to be not well enough known as to match the present statistical accuracy of our life time measurement. Table 1 shows the systematic errors on the Ni2001 data, which constitute the main bulk of coherent atomic data. The first line shows the systematic errors of the signal and the K-factor as evaluated without any ancillary measurements. The statistical error on the signal (several thousand events) is $\sigma^{\rm signal}_{\rm stat} = \pm 400$ events and leads to a statistical error in the life time ($\sigma^{\tau}_{\rm stat}$) of the order of $\pm$ 0.40 fs. The systematic errors represent maximum errors obtained from different analysis methods. The main error is due to background reconstruction. The total maximum systematic error on the lifetime is $\sigma^{\tau,{\rm total}}_{\rm syst} = \pm 1.72$ fs, thus more than four times bigger than the statistical error.

We therefore have exploratorily used a multi-layer target (less atomic break-up) and compared with the single layer target, both targets having the same thickness. In an appropriate combination of the two measurements the signal can be made disappear and the background alone remains. This background then is scaled up to the Ni2001 data and the signal is deduced. The measurement was successful but statistically not yet sufficient. The error estimates are shown in table 1, second line (with 2002 background). The error on the signal includes only the statistical error on the background from the single/multi layer target measurement (6550 ± 172 events), the error on the K-factor is reduced because of the independently obtained ratio of single to multi layer target break-up probabilities. The total systematic error of the lifetime is still about two times larger than the statistical one.

Our request for beam time in 2003 was made in order to constrain the systematic uncertainties to below the statistical errors. This implies alternating measurements on single- and multi-layer targets. Parasitically we measure at the same time the multiple scattering in our momentum domain with an accuracy of better than one percent [1]. The resulting systematic uncertainties are listed in table 1, third line (after 2003). The error on the signal extraction includes not only the three times higher statistics of the background measurement but also the better understanding of CC-background thanks to the single/multi layer target measurement. Likewise, the error on the K-factor includes the new measurements on the multiple scattering and better normalisation due to the better understanding of the CC-background. The total systematic error of the lifetime is expected to be about half the statistical error.

Table 1: *Systematic errors due to signal reconstruction, and due to the K-factor for the Ni2001 data. Line 1 contains max. errors. In line 2 the systematic error for the signal is due to the purely statistical error of the background, max. systematic errors for the K-factor. Errors in line 3 are uncorrelated errors. The last column provides the total systematic error. This error is blown up because of the strong nonlinear dependence of the break-up probability from the lifetime.*

		$\frac{\sigma^{\rm signal}_{\rm syst}}{\sigma^{\rm signal}_{\rm stat}}$	$\sigma^{\tau,{\rm signal}}_{\rm syst}$[fs]	$\sigma^{\rm K-factor}_{\rm syst}$[%]	$\sigma^{\tau,{\rm K-factor}}_{\rm syst}$[fs]	$\sigma^{\tau,{\rm total}}_{\rm syst}$[fs]
1)	without 2002	$\pm$ 5	$\pm$1.00	$\pm$15	$\pm$0.42	$\pm$1.72
2)	with 2002 background	$\pm$2.3	$\pm$0.60	$\pm$10	$\pm$0.30	$\pm$0.92
3)	after 2003	$\pm$0.6	$\pm$0.14	$\pm$2	$\pm$0.06	$\pm$0.15

Conclusion: Systematic errors strongly dominate our lifetime measurement. The multilayer target measurement of 2002 has improved the situation, but the systematic errors are still larger than the statistical error. Only the requested beam time in 2003 will allow us to make the necessary measurements for getting full control of the systematic errors.

[1] Multiple scattering is presently known to only 5%