Memorandum

To:	D.Cassel, Y.Karyotakis, H.Schellman: LHCC Referees for LHCb
From:	D.Websdale: convenor LHCb RICH
Subject:	Removal of Tracker T11 and extension of RICH 2

1 Introduction

Reconstruction of the Cherenkov angle from photon hits recorded in the RICH detectors requires a measurement of the charged track direction. The baseline (Technical Proposal) set of tracking stations included T1 and T2, for RICH 1 and T10 and T11 for RICH 2. These were foreseen to provide a precise measurement of track coordinates at the entry and exit of both RICH 1 and RICH 2. These tracking stations included horizontal strips, which are not used in the track-finding algorithms. Furthermore, no coordinate measurement in T11 is used, either for seeding or for track following.

Tracking layers with long horizontal strips are difficult to construct and suffer from a high occupancy. Within the RICH and Tracking group a new[1] study has been carried out [1] to assess the influence of these tracking chambers on the RICH particle ID performance, particularly for the high momentum tracks where the $\pi-$K separation approaches the 3σ level near to 90GeV.

This memorandum summarises the results from this study, which resulted in a recommendation to remove T11 and to extend RICH 2 by 33 cm. A study of the consequences for the RICH 2 mechanics and for its installation in LHCb revealed no problems. At the LHCb Collaboration Board in May 2001 this recommendation was endorsed.

2 Precision in measurement of track angle in RICH 2

Simulations of B$\rightarrow$ $\pi\pi$ events were used to assess the precision in measurement of the track angles at the mid-point of RICH 2. Two tracking station configurations were tested:

- T11, with horizontal and vertical strips (as in TDR)
- No T11

A comparison of the true track angle with that obtained by propagating the reconstructed track through RICH 2 verified that the role of T11 is to provide a measurement of the multiple Coulomb scattering in T10 and in the entrance window and radiator of RICH 2. For high momentum tracks the increased lever arm provided by T11 is beneficial to the angular precision.

[1] Earlier analyses, to understand the influence of the tracking precision on the RICH particle identification performance used a momentum independent smearing to parameterise the effect.

	T11 on	T11 off
$c_1(x)$ [mrad]	0.042	0.062
$c_1(y)$	0.048	0.068
$c_2(x)$ [mrad.GeV]	1.53	1.46
$c_2(y)$	1.87	2.22

Table 1: parameters giving the track angle precision, as obtained from reconstruction with and without T11 measurements

The momentum dependence of the track angle precision is well parameterised by

$$\sigma_{track}^2 = c_1^2 + \left(\frac{c_2}{p}\right)^2 .$$

where the values of c_1 and c_2, with and without T11, are listed in Table 1. For example, a track of momentum p= 70 GeV/c will have an error in the angle at entry to RICH 2 of 0.08 mrad (0.10 mrad) when reconstructed with (without) measurements from T11.

3 RICH 2 particle ID performance

The RICH pattern recognition algorithm was run on the simulated data for three detector configurations:

- T11, with horizontal and vertical strips (as in TDR)
- No T11
- No T11, but increased photon yield (+18%), corresponding to extending RICH 2 by 33 cm into the region occupied by T11.

The significance of π–K separation, measured by N_σ, is plotted as a function of the track momentum in Figure 1. This figure shows that the high-momentum performance is not degraded by the removal of T11.

Particle identification matrices, resulting from the global likelihood analysis, were obtained and the results are summarised in Table 2, for three ranges of charged particle momentum. Again, the effect of using information from T11 is small. Detailed examination of the data shows that removing T11 results in a small performance degradation, but this is recovered when the additional 18% photon yield is included.

4 Photon yield in RICH 2

The particle identification without T11 is recovered by extending RICH 2 33 cm into the region liberated by T11. However it is important to emphasise that the photon hit count from RICH 2 leaves little margin to accommodate any loss compared with the number of

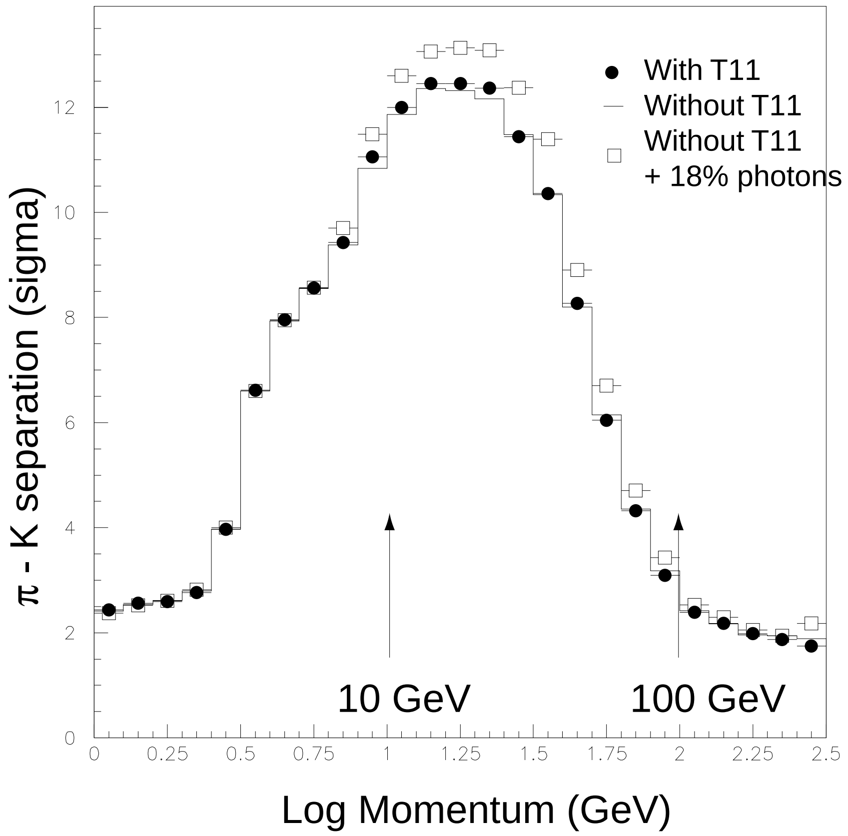

Figure 1: Number of sigma separation between pion and kaon hypotheses for true pions, as a function of momentum

	PIONS			KAONS		
p range [GeV]	%	T11 on	T11 off	%	T11 on	T11 off
$p < 20$	eff	85.8	85.7	eff	78.9	79.1
	purity	98.3	98.0	purity	65.8	67.6
	$\pi \rightarrow$Kp	2.3± 0.1	2.0± 0.6	K→e$\mu\pi$	6.8± 0.4	7.0± 0.4
$20 < p < 70$	eff	55.8	56.8	eff	95.9	96.2
	purity	97.7	96.2	purity	93.2	91.6
	$\pi \rightarrow$Kp	1.4± 0.1	1.0± 0.1	K→e$\mu\pi$	0.8± 0.2	0.6± 0.2
$p > 70$	eff	29.4	29.2	eff	78.4	81.9
	purity	95.1	94.7	purity	50.4	48.2
	$\pi \rightarrow$Kp	11.6± 0.9	12.1± 1.0	K→e$\mu\pi$	19.0± 3.2	18.1± 3.2

Table 2: Particle identification performance (efficiency, purity, misidentification probability) for true pions and kaons in the low, mid and high-momentum bands. In the "T11 off" configuration the Cherenkov photon yield was increased by 18%.

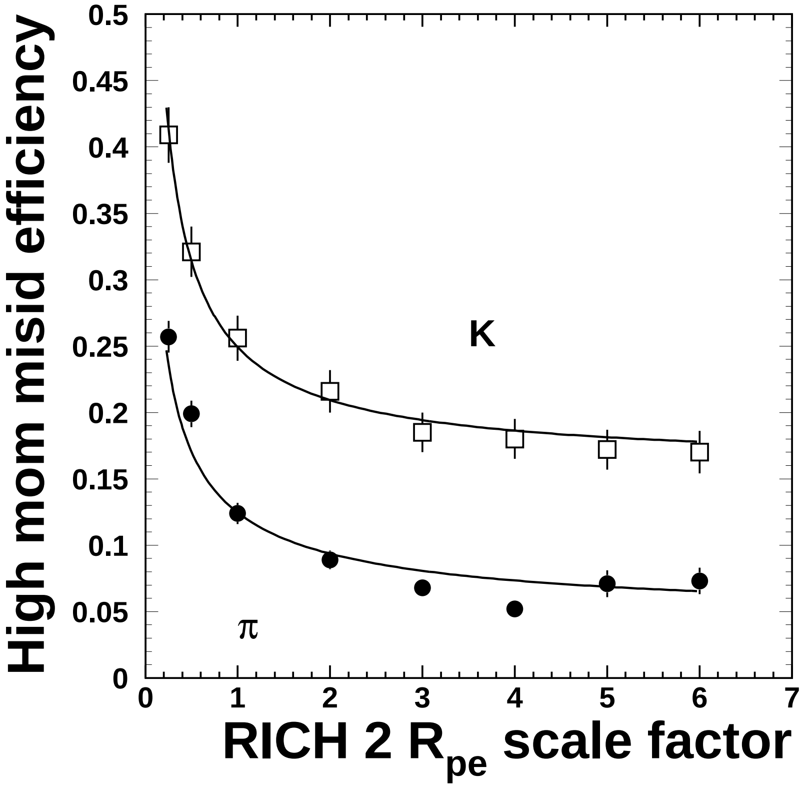

Figure 2: High momentum misidentification for pions and kaons, as a function of the relative photon yield in RICH 2

hits anticipated, e.g. due to a possible ageing effect of the photocathodes. The global misidentification rates for pions and kaons is shown in Figure 2, for different assumptions of the photon yield. The value $R_{\text{pe}} = 1$ corresponds to 19 photoelectron hits, obtained with the RICH 2 radiator length as defined in the RICH TDR.

5 Extended RICH 2

Extension of RICH2 by 33 cm requires a re-optimization of the parameters of the optical system, viz. mirror radius and tilt angle, position of photon detectors, etc. A first iteration of the optical layout is shown in Figure 3 (minor adjustments will need to be made to accommodate tolerances for window distortion under pressure differences). The mechanical structure of RICH2 is extended by 33 cm in z, which still allows the entire assembly to be lowered into the cavern through the 10 m diameter access shaft.

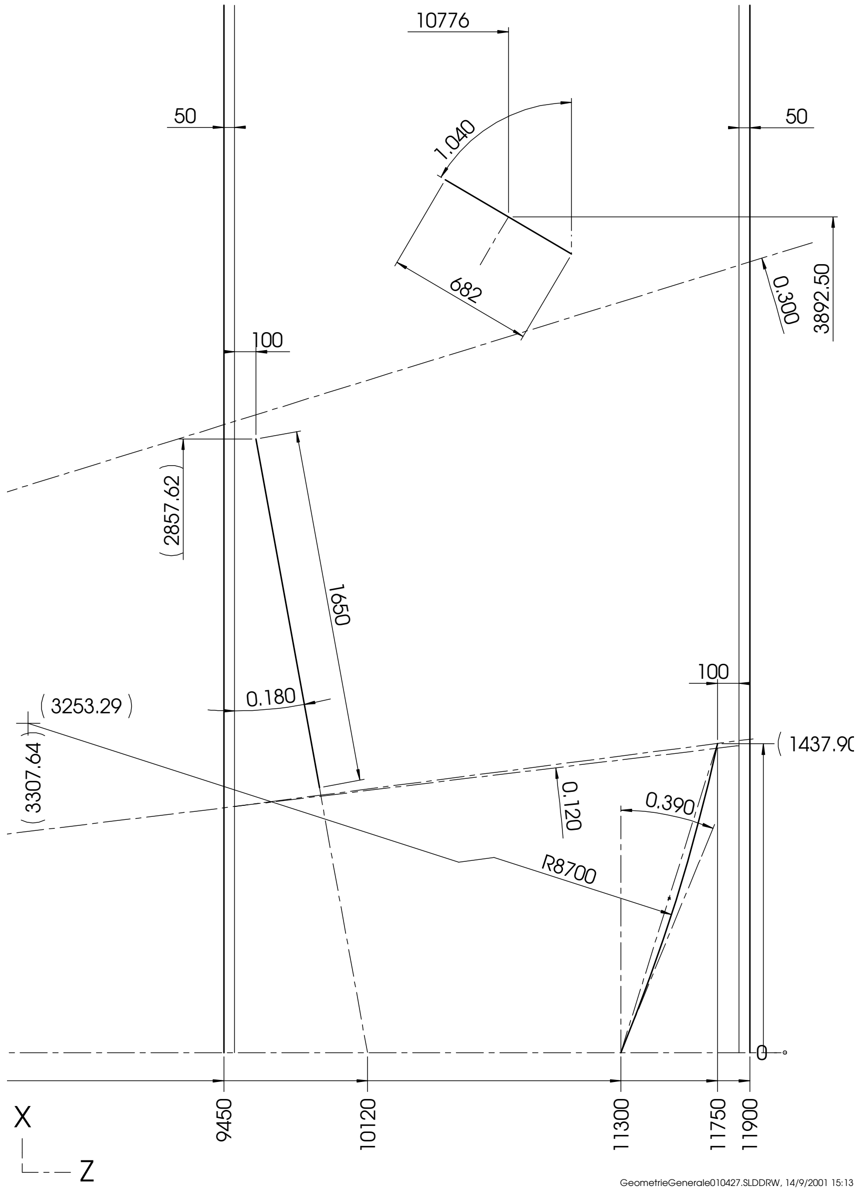

Figure 3: Optical layout for extended RICH 2

6 Summary

1. The potential usefulness of T11, in providing an improved error of the charged particle direction in RICH 2 (effectively by measuring multiple scattering in the entrance window and radiator gas) is partially cancelled by scattering in the mirror assembly and exit window.

2. RICH particle ID performance at high momentum ($p > 70\,\mathrm{GeV}/c$) without T11 shows only a small degradation, which is recovered by increasing the photon yield by 18%, corresponding to an extension of RICH 2 by 33 cm into the region occupied

by T11.

3. The particle ID performance as a function of photon yield shows that we cannot afford to lose photons in RICH 2.

4. The extension of RICH 2 involves a modification of the parameters of the optical system and of the vessel dimensions. However there are no differences in principle from the mechanical layout and the installation procedures as described in the TDR. Apart from the removal of T11 no other LHCb sub-detector is affected.

References

[1] M.Benayoun, R.Forty and G.Wilkinson, "Tracking, Tracker Layout and RICH performance". LHCb 2000-100 RICH http://documents.cern.ch/archive/electronic/cern/others/LHB/public/lhcb-2001-100.pdf