Some interesting numbers for the MIPP RICH

Rajendran Raja
14-Feb-2002

I calculate some interesting quantities that characterize the performance of the MIPP RICH. The object here is to study the impact of the momentum resolution (degraded by a ToF system) on particle Id by the RICH.

Figure 1 shows the refractive index of Co2 and the quantum efficiency of the phototubes as a function of the wavelength of the Cerenkov light. (Thanks Sharon).

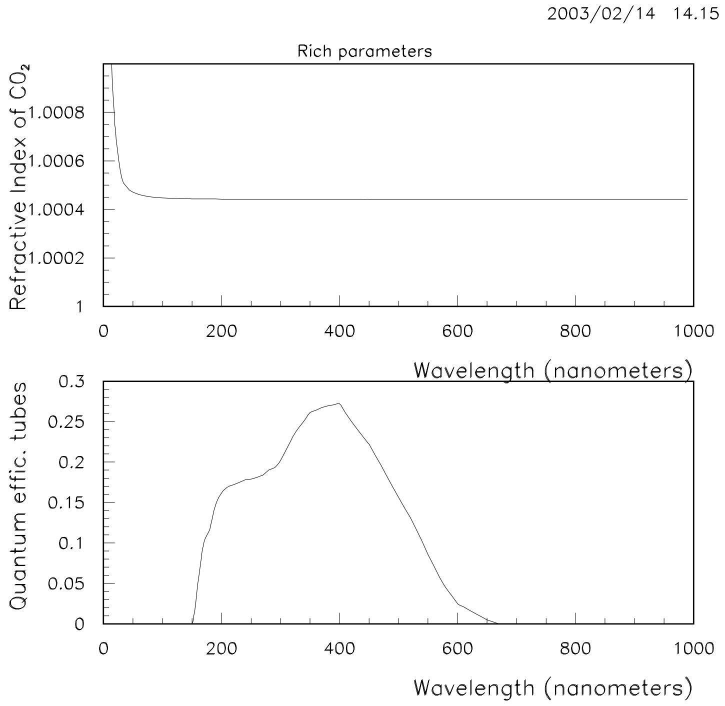

Figure 1Refractive index and average quantum efficiency as a function of wavelength

The average focal length of the mirrors is 991.504 cm and the average refractive index is 1.00048. Using these values, I calulate the Cerenkov ring radius as a function of momentum for the three particle species as shown in Figure2.

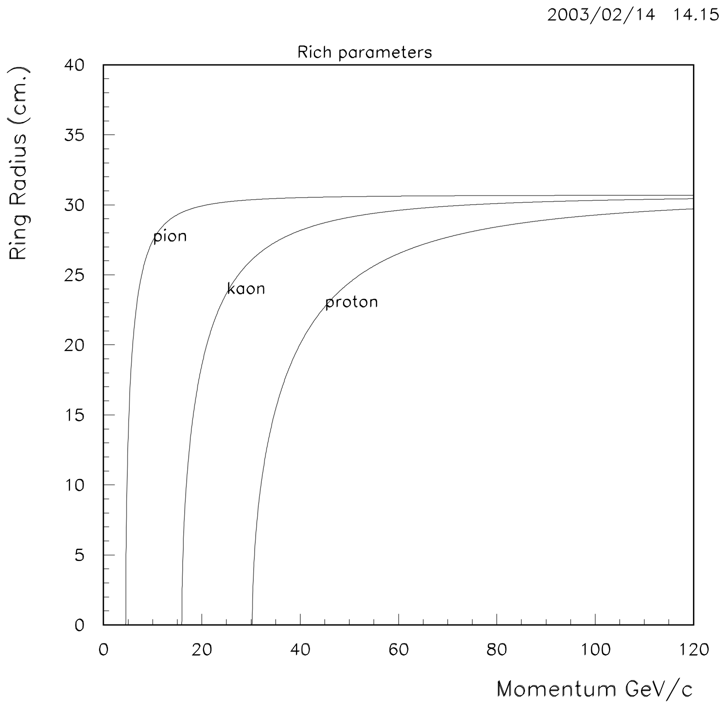

Figure 2 Ring radius as a function of momentum in MIPP

The ring radius for a β=1 particle in MIPP is 30.71cm and 11.45 cm in SELEX. The sine of the Cerenkov angle, sin θ_c =0.03097 radians in MIPP and 0.01155radians in SELEX. The Cerenkov light emission is given by the formula

$$\frac{dN}{d\lambda} = \frac{z^2 2\pi\alpha}{\lambda^2} L \sin^2 \theta_c$$

where N is the number of photoelectrons emitted, λ is the wavelength of light, α is the fine structure constant, z is the charge of the particle (=±1 for all our particles), and L the path length of the particle in the radiator. One can integrate the above formula, folding in the quantum efficiency of the tubes as a function of wavelength. This yields the total number of photons N, assuming 100% collection efficiency.

$$N = N_0 L \sin^2 \vartheta_c$$

where N_0 is a constant that is independent of the Cerenkov angle and the gas used. It should be the same in MIPP and SELEX. Doing the above integration yields N_0=364cm^{-1}, whereas the measured N_0 for SELEXis 108.3 in the central region. This implies that there is a light collection (as well as maybe other) efficiency of 0.297 on top of the tube efficiency. The SELEX numbers are taken from J.Engelfried et al, NIM A431, 1999.

Table 1 makes a comparison of MIPP and SELEX performance numbers. To calculate the number of photoelectrons, we have assumed the SELEX N_0=108.3 for the central region. MIPP has on average 7 times more photelectrons in the ring than SELEX. However, the average ring is too large to fit in the detector, so MIPP sees perhaps half this number on average.

The perimeter of the β=1 ring in MIPP is 193cm. The separation between the centers of phototubes is 1.613 cm, so a complete ring will see 120 tubes. In SELEX this number would be 44.6. The average number of detected photoelectrons per tube with all efficiencies taken into account would be 0.86 in MIPP and 0.32 in SELEX. This number will scale linearly with sin θ_c.

Table 1 Comparison of SELEX and MIPP parameters

	SELEX	MIPP
Sin θ_χ for β=1 particle	0.01155 rad	0.03097 rad
Radius for β=1 particle	11.45cm	30.71cm
Number of photoelectrons	14.32	103.0
No of photoelectrons/tube	0.32	0.86
Resolution of radius	1.55mm	0.76mm

SELEX also measures the resolution of a single hit in a ring σ_h to be 5.5 mm. This quantity is also experiment independent, since it depends on phototube spacing , mirror alignment, track resolution and dispersion in the gas (weak). It does not depend on the statistics of hit tubes. The resolution of the radius of the ring σ_r is given by

$$\sigma_r = \frac{\sigma_h}{\sqrt{\text{Number of tubes hit}}}$$

This gives a radius resolution of 1.55mm for SELEX and 0.76mm for MIPP, where I have assumed that only half the ring is observed in the detector.

Equipped with these numbers it is instructive to see the difference in the radii for the various hypotheses as a function of momentum. Figure 3 shows this plot. With a resolution of ~ 1mm in the ring radius, all particles are distinguishable up to the maximum momentum of 120 GeV/c!. At 120 GeV/c, the smallest difference in radius is the π/K difference = 0.25cm. This is ~2.5 sigma difference. Note that there are no Kaons in the experiment at these momenta.

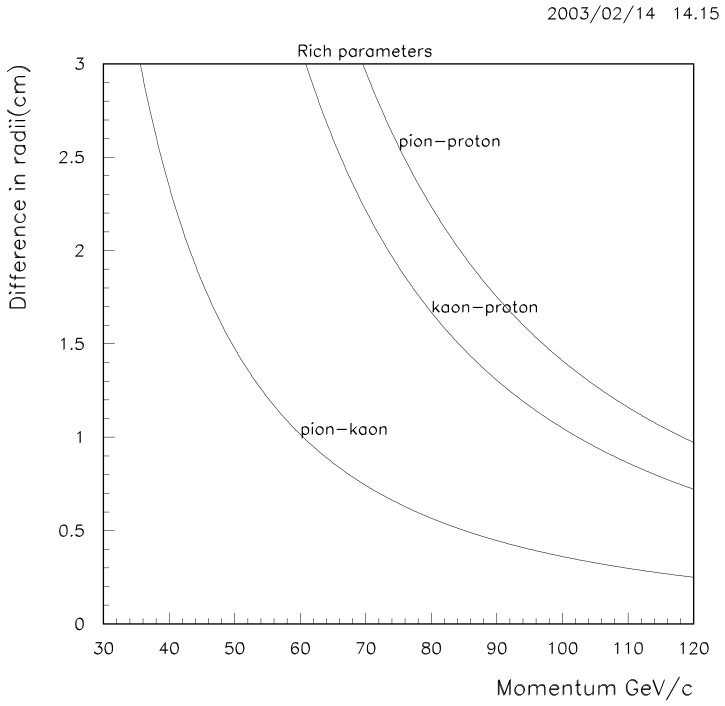

Figure 3 Difference in ring radius as a function of momentum for π–K, K-p and π-p hypotheses.

In order to make a change of 0.25cm in the Kaon radius, the momentum has to change from 120 GeV/c to ~ 80 GeV/c. The pion radius is flat with momentum to first order here, so all the change is in the Kaon radius. This is a 30% change in momentum! No TOF system can introduce that large a momentum measurement error, so we are safe in the RICH against ToF momentum errors. To be more quantitative, at 80GeV/c, the pion radius is 30.66cm and the Kaon radius is 30.096cm. At 120 GeV/c, the pion radius is 30.69cm and the kaon radius is 30.44cm. In order for an 80GeV/c pion to be confused with a Kaon, the momentum has to be mismeasured by 40GeV/c.

The momentum uncertainty at 80 GeV/c with a 5cm ToF (C.Rosenfeld, February 8, 2003 collaboration meeting) is ~3% . So we are safe against momentum smearing due to multiple scattering by a 5cm ToF. This safety is a result of the flatness of the pion Cerenkov angle as a function of momentum at these momenta.