Studies of the effects of multiple Coulomb scattering and measuring errors on the Cerenkov emission angle reconstruction.

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1 Purpose :

The aim of this study is to evaluate the contribution to the Cerenkov emission angle resolution in RICH 1 due to :

a) the multiple Coulomb scattering (MCS) the particle undergoes traveling from the entrance to the exit windows of the RICH vessel,

b) the errors (MRR) with wich the particle track direction and position are measured at the upstream and downstream tracking detectors.

2 Assumptions :

a) The reconstruction method used for this study has already been described (see COMPASS / RICH / PS / Report 2); it is based on the reconstruction of the emission angle of each detected photon, assuming that it has been emitted at the centre of the particle path inside the radiator ('average' emission point).

b) For the reconstruction it is assumed that the particle trajectory has been measured with a fairly good precision.
What we want to know with the best accuracy is the position of the centre of the particle path inside the radiator (assumed as the photon emission point) and, but less critical, the position and the direction of the particle at the impact point on the mirror, to compute the 'reflected' particle path.
We do not make detailed assumptions on the tracking devices type and characteristics; we assume that the particle path is known at the RICH entrance window both in position and direction. How this can be achived is matter of discussion, both from the point of view of the precision and the efficiency.

c) To deal with a 'reasonably' realistic sample of particles, we read a file of MC particles generated by the LEPTO code (a typical sample of deep-inelastic-scattering final states) and then processed by COMGEANT (μ-beam set-up as from the COMPASS

Proposal) to simulate the up-stream part of the experimental apparatus, including the magnetic field of Spectrometer 1 ('box' field approximation with acceptance determined by the magnet yoke and poles).

3 Simulation :

The simulation is simple, at a first order of approximation;

a) The MCS is simulated at generation level;
the particle undergoes finite steps of MCS at :
- the aluminum of the vessel entrance window (2. mm width),
- the radiator gas (C4F10) between emitted photons (fixed to 30 for each particle),
- the mirror material (Pyrex, 5. mm width),
- the mirror wall material (aluminum, 4. mm equivalent width),
- the gas between the mirror and the end of the vessel,
- the aluminum of the vessel exit window (2. mm width);

at each step the particle position and direction are computed, including an hypothetical detector plane at 500. mm downstream the exit window;
energy losses are neglected.

b) In the reconstruction, the particle direction is computed from the position of the particle at (or projected at) the entrance window and that on the downstream detector, assuming both measured;
this means that also the MCS in the material downstream the mirror contributes to the Cerenkov angle resolution.

c) For MRR simulation we use the two measurements of the particle trajectory; the 'true' positions are smeared according to the measuring errors and the 'measured' trajectory position (at the entrance window) and direction are computed to enter the reconstruction procedure.

4 Results :

Various MC runs have been done to study the different contributions :
in each run 6000 particles are processed and 30 photons are generated for each particle, rejecting the particles and the photons that do not point at the upper mirror;
particles with momentum lower than $5.GeV/c$ are also rejected;
The results are summarized in table 1, where :
the r.m.s. of the distribution of $\Delta\theta = \theta_{reconstructed}$ - $\theta_{generated}$ is reported in the second column;
MCS means multiple coulomb scattering of the particle through the different RICH parts,
MRR means measuring errors on particle trajectory; σ is the $x-$ and $y-$position resolution at the entrance and at the exit (+ $500.mm$) window planes,
$pixel$ means the effect of the photon detector $8.mm \times 8.mm$ pixel on its detection point measurement;
in the first part of the table the MCS contributions of different parts of RICH are shown;

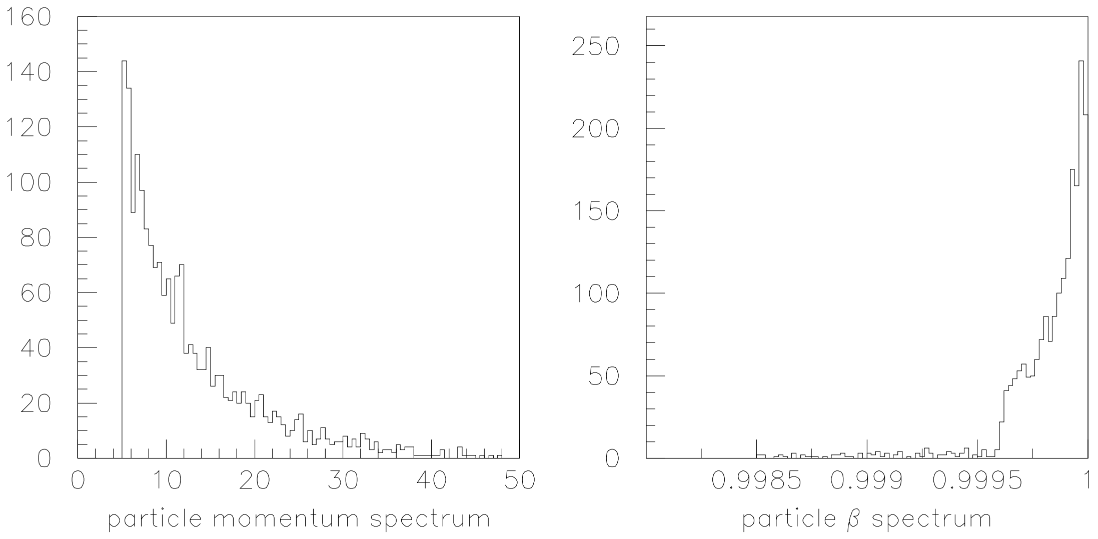

Figure 1: The momentum and β spectra of the particle sample used in the simulation.

all means entrance window, radiator gas, mirror and the rest down to the tracking detector;
the entrance window is responsible for an average dispersion in the particle projected angle of a r.m.s. of 0.23 $mrad$, the radiator gas (full length) for 0.45 $mrad$, the remaining materials before the downstream detector for 0.48 $mrad$; to evaluate the effect on the $\Delta\theta$ r.m.s., it assumed to measure one point upstream and one downstream on the particle trajectory;
in the second part of the table the measuring errors in the particle trajectory are taken into account; in this exercise the errors are assumed to be equal to the specified value both in $x-$ and $y-$projections and in up- and down-stream detectors;
in the third part the error sources are combined;
the fourth part of the table is for comparison.

5 Conclusions :

The most important (and unavoidable) contribution to MCS is due to the radiator gas; the effect (relevant up to the impact point on the mirror) is a 13. % decrease in the emission angle resolution in the case in which only the spherical aberrations are taken into account;
the decrease in resolution due to the particle measuring error is a function of the magnitude of this error; to get, e.g., a contribution comparable to that of MCS the measuring error σ should be of the order of 2.5 mm (e.g. tracking chambers with a pitch of $\sim$ 10. mm) over a lever arm of $\sim$ 3.5 m; in fact this contribution should be kept 'negligeable' (in the squared sum) with respect to MCS (typically $\sigma \leq 0.8$ mm).
For comparison, if we make the hypothesis that the particle tracking is done upstream the RICH only, a reasonable useful lever arm is $\sim$ 70. cm; to get an equivalent accuracy in the direction of the particle trajectory at the entrance window, we should achieve a $\sigma \sim 5$ times less than in the previous case ($\sigma \leq 0.16$ mm) or better.
It must be stressed that all these figures are valid in the hypothesis of a 100 % efficiency of the tracking detectors and of the pattern recognition procedure.

$error\ source$	$PAWrms$ μrad	$conditions$ p in GeV/c
MCS : entrance window only	0.	NO sph. aberr., $p > 5.$
MCS : en. win. and radiator gas	39.	NO sph. aberr., $p > 5.$
MCS : all	43.	NO sph. aberr., $p > 5.$
MCS : all	12.	NO sph. aberr., $p > 40.$
MCS : all	106.	$p > 5.$
MRR : $\sigma = 0.25\ mm$	10.	NO sph. aberr.
MRR : $\sigma = 1.\ mm$	16.	NO sph. aberr.
MRR : $\sigma = 2.5\ mm$	37.	NO sph. aberr.
MCS : all, MRR : $\sigma = 0.25$	49.	NO sph. aberr., $p > 5.$
MCS : all, MRR : $\sigma = 0.25$	109.	$p > 5.$
MCS : all, MRR : $\sigma = 0.25$, pixel	181.	$p > 5.$
spherical aberr. only	95.	
pixel only	156.	NO sph. aberr.
spherical aberr. and pixel	172.	

Table 1: Resolution in reconstructed Cerenkov angle (RICH 1), with particle multiple coulomb scattering and measuring errors on particle trajectory. See the text for details.