BTeV Document xxxx
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# Hardware Alignment of the BTeV RICH System

**Abstract**

The BTeV RICH system has to be properly aligned with hardware and data in order to fully exploit its particle identification power. We describe in this note the proposed hardware alignment methods during installation and running.

## 1. Introduction

The design goal of the BTeV gas RICH system is to provide the Cherenkov angle resolution about 0.1 mrad per track. The error mainly consists of chromatic error, emission point error, and segmentation. Proper alignment is necessary to ensure the quality of the detector. In this note we describe conceptual hardware alignment during installation and run time alignment quality monitoring. More precise alignment using isolated track data will be discussed elsewhere.

## 2. Mirror alignment during installation

The BTeV RICH detector has two spherical mirror halves with a curvature of 7 meters. Each mirror half consists of 18 full hexagons and 6 half hexagons. The two halves are tilted at 261 mrad with respect to the beam direction. The distance from the entrance window of the gas radiator to the mirrors is about 3 meters. All small mirror segments (hexagons and half hexagons) will be mounted on a support structure with three screws per segment forming an adjustment mechanism.

All mirror segments will be mounted and aligned roughly with eye before fine adjustment. Once they are mounted, we may leave the whole system for some time to allow the deflection of mirror supporting panel due to weight. The LHCb RICH group observed that the main relaxation of their system especially the screws occurs during the first 5 days. Of course this all depends on the rigidity of the system and if heavy glass or lightweight carbon fiber mirrors are used.

We have two methods for fine adjustment of each mirror panel. Both methods require quite a large space, more than 7 meters perpendicular to the window plane. The fine adjustment will be made in the C0 assembly hall. Coordination with other sub-detector groups is necessary so that the RICH group will have enough space and time for this operation.

The support structure including mounting panels will be surveyed first and reference axes and focus points will be defined.

The first method requires a laser point source and a CCD camera. These two will be used for mirror quality testing prior to the installation. As shown in Figure 1, a theodolite will be employed to determine the desired center of curvature of the mirror to be aligned. The center of the laser point source and the CCD camera will be sited at this point. If the mirror is perfectly aligned, the image of the laser point source will be at the center of the CCD screen. Viewing by eye, one can determine the displacement to the order of 1 mm, corresponding to the tilting angle of the mirror about 0.1 mrad. An online program can be created to perform a simple center of gravity analysis of the image. The alignment precision will then be much improved. This method provides continuous view during adjustment. It also allows monitoring over a long period for environmental effects.

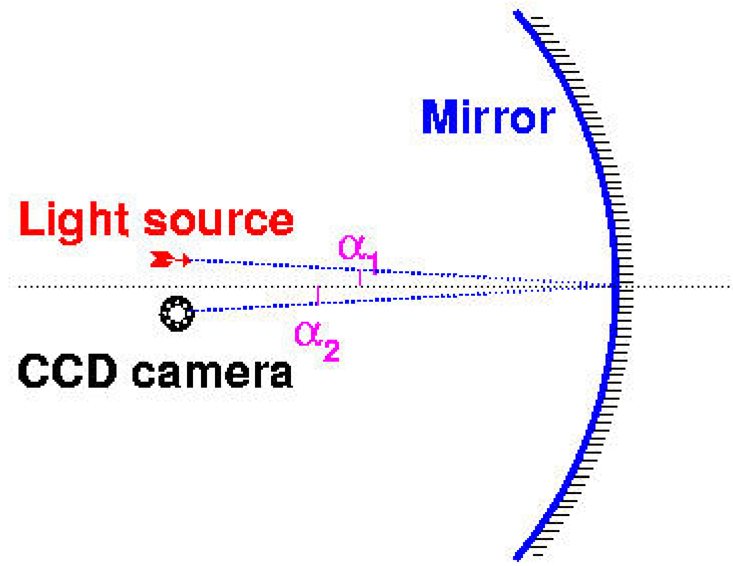


**Figure 1:** Mirror alignment using point light source and CCD camera.

The second method is to use a theodolite directly with the function of "auto-collimation" as shown in Figure 2. This method was used by the COMPASS experiment. The auto-collimation function is for the perpendicular alignment of a plane mirror. It works in the similar fashion for a spherical mirror as we can place the theodolite at the desired center of curvature. The observer brings a projected reticule into alignment with the standard reticule. Misalignment of the mirror causes the reticules to be displaced with respect to one another. The method could provide much superior precision than the first method.

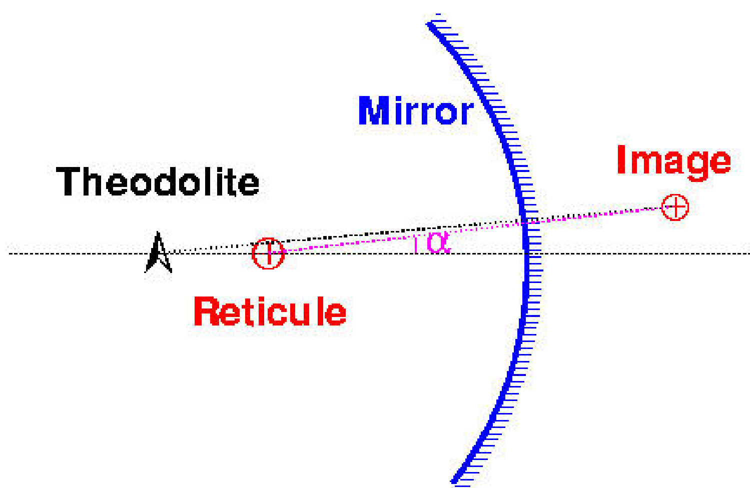


**Figure 2:** Mirror alignment using theodolite.

## 3. Alignment of HPD arrays and PMT arrays

The HPD and PMT arrays will be installed in the C0 collision hall after the Straw Tube installation is complete. Unlike the mirror alignment, the alignment of HPD and PMT arrays does not require large space. The HPD and PMT beehives will be surveyed with respect to reference points already defined for the RICH super structure. Since the photon detectors will be outside the acceptance of the main detectors, we can afford material budget to make the beehives rigid and precise. The locations of individual HPD's and PMT's within the beehives are well determined by the mounting procedure. The rigidity of the beehives will be sufficient not to worry about deformation of the beehive structures. Thus for hardware alignment of the photon detectors, we only need to align the beehive structure with respect to super structure and tracking system.

The precise alignment of individual HPD's and PMT's will be performed with real data. Individual PMT's will be aligned with data using large angle tracks, which hit the PMT's. In this way the PMT's are directly aligned with the BTeV tracking system. Due to the location and magnetic shield individual HPD's can not be aligned using tracks directly. The HPD's can be aligned together with the mirrors using Cherenkov photons from isolated tracks, or using collimated laser light reflected by the mirrors.

## 4. Mirror and HPD array alignment monitoring system

The alignment of the optical system may change during running. With the data of isolated tracks one can make precise alignment. However, there is an ambiguity since the photons of the Cherenkov ring may not be reflected by only one mirror segment since the emission point is uncertain. It would be nice to have a separate method to monitor the alignment.

We can use collimated light sources for each mirror segment to determine the alignment with the readout of HPD's. From the readout point of view, the best position of the light source would be at the entrance window to mimic the Cherenkov photons. On the other hand we have to minimize the radiation length of the material in detection volume. We can also place optical fibers at the mirror plane and mount them on the corners of each mirror segment to mimic the reflected Cherenkov photons. This may complicate the design.

Figure 3 shows a possible better solution. An array of collimated beams of light via radiation hard single mode optic fibers will be placed at the side of the vessel near or between PMT's. The reflected light by the mirror will be detected by the HPD arrays on the opposite side of the detector. In order to monitor alignment of all mirror segments, the light sources will be placed between 25 cm to 100 cm from the mirror plane, with angles of about 40°–70° with respect to the beam direction in xz plane. The position and the direction of the light sources can be optimized depends on the technical difficulty and that if we need to align HPDs in this way.

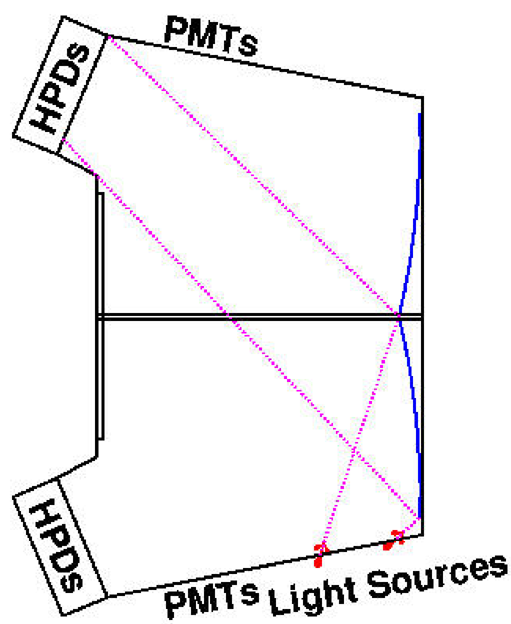

**Figure 3:** Alignment during running with collimated light sources mounted on the side of the RICH vessel.

From the readout of HPD's one can monitor the change of alignment with the effects from both the mirrors and HPD's. To disentangle the effects we can have a separate laser sources for monitoring the HPD arrays alignment. Or we can rely on alignment of the HPD bee-hive structure with the method same as alignment monitoring of support structure described in next section.

The main difficulty of this method is how to ensure the direction of the light source be as stable as the detector.

## 5. Alignment monitoring of the supporting structure

During running, with changing temperature, magnetic field, and other sources the supporting structure may have deformations. We need an automatic system to monitor the status periodically. To achieve this we can use inexpensive semi-transparent position sensitive silicon sensors. We will use a collimated laser sources via single mode optical fibers and total or semi reflection mirrors.

Again the difficulty for the alignment here is how to achieve stable laser alignment references. We will have a structure independent of the RICH detector. The alignment of such structure with the tracking system is also needed.

## 6. Summary

Possible alignment methods are discussed in this note. For the mirror alignment during installation, method either with combination of a laser point source and a CCD camera or with a theodolite in mode of "auto-collimation" should provide high quality. We can use collimated light source mounted at the side of the RICH vessel to monitor the alignment of the mirror and the HPD arrays. For the supporting structure we can use position sensitive silicon sensor based alignment tools.