Alignment Requirements for the MVD and BB counters

H. van Hecke
Los Alamos National Lab
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1 MVD

1.1 Strip detectors - internal alignment

In this section, we assume that the overall device has been placed exactly in its nominal position, and examine the requirements on the internal chip placement due to the so-called correlation method of vertex finding. In this method, the pattern of hits on the inner barrel can be correlated with the pattern of hits on the outer barrel: since tracks are initially almost straight, the patterns are related by a simple scale factor R_1/R_2, where R_1 and R_2 are the radii at which the inner and outer chips are placed. The method relies on a track firing strip pairs that obey this scaling rule.

Some chip placement aberrations result in a track ending up in a strip neighboring the expected one, reducing the peak value of the correlation function. Preventing this kind of error defines most of the constraints on placement of the chips in 3 directions, z (along the beam axis), R (radial), and s (circumferential, or R*dϕ), plus the 3 rotations around these axes. The chips lie at radii R_1 and R_2, which are 5 and 8.0 cm, respectively. The size of a chip in the z-direction (Z_{chip}) is taken to be 5.3 cm, and the detector "cylinders" have a hexagonal cross-section.

The correlation method is only concerned with the relative placement of chip pairs, one chip on the inner cylinder and the corresponding chip(s) on the outer cylinder. Here, one example of the determination of the alignment constraints is given. The other constraints are determined similarly and are summarized in table 1.

Consider the displacement in R (ΔR) of one of the cylinders relative to the other. When scaling the outer pattern by the nominal R_1/R_2, a radial displacement would result in a pattern that is improperly scaled. A calibration procedure could find the actual R_1/R_2, but the nominal ratio will presumably be a ratio of integers, potentially hard-wired in a fast vertex finder. In order to limit the error such that in the worst case, a track is displaced by 1 strip (200μm),

$$200\mu m = \frac{R_1}{R_2} \times \frac{Z_{chip}}{R_2} \times \Delta R \tag{1}$$

This is satisfied if radial displacement of the outer chip is less than ≈0.4mm.

axis	max. error in relative position	max. error for relative rotation about this axis
z (beam)	0.7mm	0.2°
R (transverse)	0.4mm	0.3°
s (circumference)	0.5mm	0.3°

Table 1: Summary of tolerances in placement of inner/outer chip pairs relative to each other from correlation method

These tolerances, summarized in table 1, are between inner/outer chip pairs only. Suppose that a chip pair is joined such that they meet these tolerances. There are further constraints on the positions of chips pairs relative to the beam. Again, consider one example. There is a constraint in R, which leads to a limit of:

$$dR \times \frac{R_2 - R_1}{R_2} \times \frac{Z_{chip}}{R_2} \times \frac{R_1}{R_2} = 200\mu m. \tag{2}$$

The pair must be placed at a radial distance which is known better than dR ≈0.8mm. This should be compared to the size of the Au+Au beam in the transverse direction[1,2], σ_T ≈0.45mm. Table 2 summarizes the constraints on the positions of pairs of chips relative to the beam. These constraints are not as stringent as those on the relative positions of the chips.

axis	max. error	max. error for rotation about this axis
z	2.0mm	1°
R	1.3mm	16°
s	∞	1°

Table 2: Summary of tolerances on the placement of chip pairs relative to the beam from correlation method, where each pair of chips are positioned relative to each other within the tolerances given in table 1.

The correlation method of vertex finding leads to the limits given in tables 1 and 2. The pseudo-tracking method combines a hit on any of the inside chips with a hit on any of the outer chips, which may pose limits on the relative placement of all chips simultaneously, not just in pairs. In order for this method to work, all pairs must be able to point to the same vertex. This implies relative placement requirements between any pairs of chips similar to those in table 1. However, this is an offline method, and the positions of chips may be calibrated using tracks reconstructed from other detectors. Such calibrations would work for all aberrations except rotations around r and z. However the tolerances imposed on these angular placements by the correlation method are much more stringent than anything needed to define a vertex to 1mm. Thus the pseudo-tracking method imposes no further restrictions.

1.2 External alignment

In the preceeding section, the internal chip placement criteria were formulated based on the assumption of perfect overall detector placement. From table 2 we can also conclude that displacement in R of 1.3 mm of the entire device would lead to a failure of the correlation method of vertex finding. The remaining constraints on the global placement of the MVD are formulated by the other susbsystems: how well do the muons need to know the vertex, and how well does the e-arm tracking need to know the vertex (when it cannot be determined internally due to low multiplicity).

The constraints from the muon arms are on the 5-mm scale, worse than the sub-mm placement we expect to get. The e-arm tracking system has not yet explored the use of the MVD vertex.

1.3 Pad detectors

The silicon pads occupy two disks at the end of the strip detector, and are used to measure dn/dy. They are arranged in equal bins in pseudorapidity and phi. As an alignment criterium one can require that the offset transverse to the beam be smaller than a fraction - say 1/10 - of the smallest pad. The smallest pad is 2x2 mm, which leads to an alignment criterion of about 0.2 mm in R.

The placement in z of the pads relative to the strips sets the scale for the y-measurements in the pads. If the interaction vertex is in the center, one could require that the intercept of a track with a pad should not shift by more than 1/10 of a pad size due to a shift in z of the pad plane. This leads to dz = 1.2 mm.

No physics agument leads to a requirement on the global placement accuracy in phi.

Clearly physics considerations do not require alignment of the pads relative to the strips that is more accurate than the approximately 0.1 mm expected to be achieved in constuction of the MVD/pad detector already.

1.4 MVD mounting and global alignment

The MVD will be housed in a thermal/electrical enclosure, which is mounted from one of the magnet nosecones. There is 5 mm clearance between the beampipe and the inner MVD surface, so there is a little room for global position adjustment. The beampipe in turn passes through a hole in the central magnet iron, with 20 mm clearance. Some of this 20 mm will be taken up be a heating system (for baking out the beampipe).
The mounting of the MVD on the nosecone will allow for small vertical adjustment.
One item that has come up is the effect of the thermal expansion of the magnet iron. The distance of the magnet center from the hall floor (approximately 5.35 m of iron) increases by 0.6 mm for every $10°C$ increase in iron temperature. Thus we either need to have dynamic adjustment on the scale of 1-2 mm, or allow for a final re-positioning of the beam pipe and the MVD after the magnet has reached a thermal equilibrium corresponding to operating conditions. Alternatively, the movement of the magnet may be mapped out years before the MVD arrives, giving enough confidence to mount the MVD without the need for last-minute adjustment.

2 Beam-Beam counters

From a physics point of view, there are no stringent positioning requirements placed on the BB counters. All they need to do is catch the fastest particles near the detector axis. This task is to first order independent of (small) shifts in the plane transverse to the axis. Timing shifts due to repositioning errors along the axis are only 3.3 ps/mm. Thus the BB counters can tolerate many mm of error before their performance is affected. Since the expected placement accuracy is at the sub-mm level, the physics do not place additional requirements on the alignment.

3 References and Notes

1. D. Beavis, *et. al.*, **Fourth Workshop on Experiments and Detectors for a Relativistic Heavy Ion Collider**, BNL report # 52262, 235 (1990), M. Fatyga and B. Moskowitz, eds.

2. RHIC Bulletin, BNL, Vol. II, No. 3, Oct. 1991.