Review of the Geometry Monitoring System of the ALICE Di-Muon Spectrometer.

The ALICE collaboration is designed to look for the quark-gluon plasma, a new form of matter that is expected in the high energy collisions of heavy ions. ALICE is a dedicated heavy-ion detector design to exploit the physics potential of nucleus-nucleus interactions at LHC energies. The high energy and heavy ion collisions of the Large Hadron Collider are the most promising places to look for phenomena that would indicate the existence of a quark-gluon plasma.

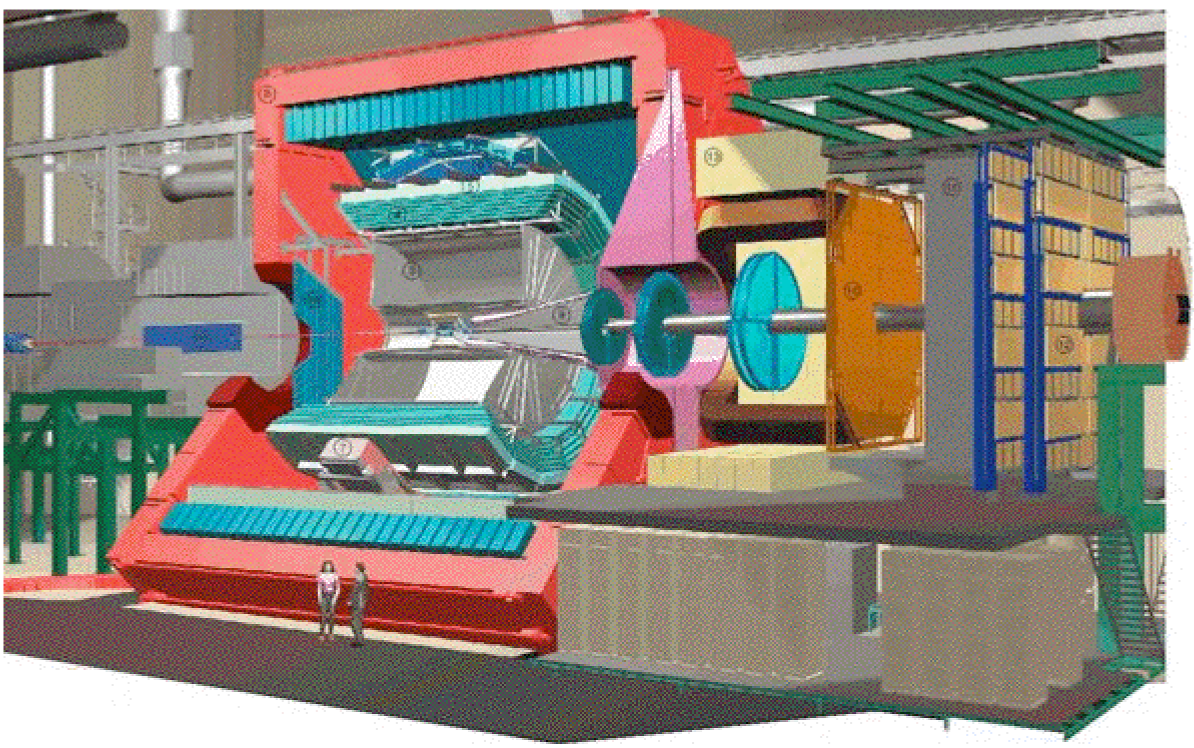


Fig. 1: The ALICE Detector

A promising signature for the existence of quark-gluon plasma is the production of heavy quarkonium states, the Upsilon and J/Psi particles. These particles can be detected by their decay into muons and reconstruction from di-muon pairs. To separate different members of the Upsilon family, the spectrometer needs to have a mass resolution of about 1% at the Upsilon mass and kinematic regions appropriate to the ALICE experiment. Since the Upsilon has a mass of about 10 GeV/c^2, the di-muon mass resolution should be about 100 MeV/c^2. This has been taken as a benchmark for the performance of the detector and is accepted for this review.

The tracking system of ALICE consists of ten planes of cathode pad chambers as shown in figure 2. The performance of chambers will not be addressed in this document. To achieve the benchmark resolution in the forward muon spectrometer, you need precision chambers and you also need to know where the precision chambers are. The monitoring system selected for that purpose is the subject of this document.

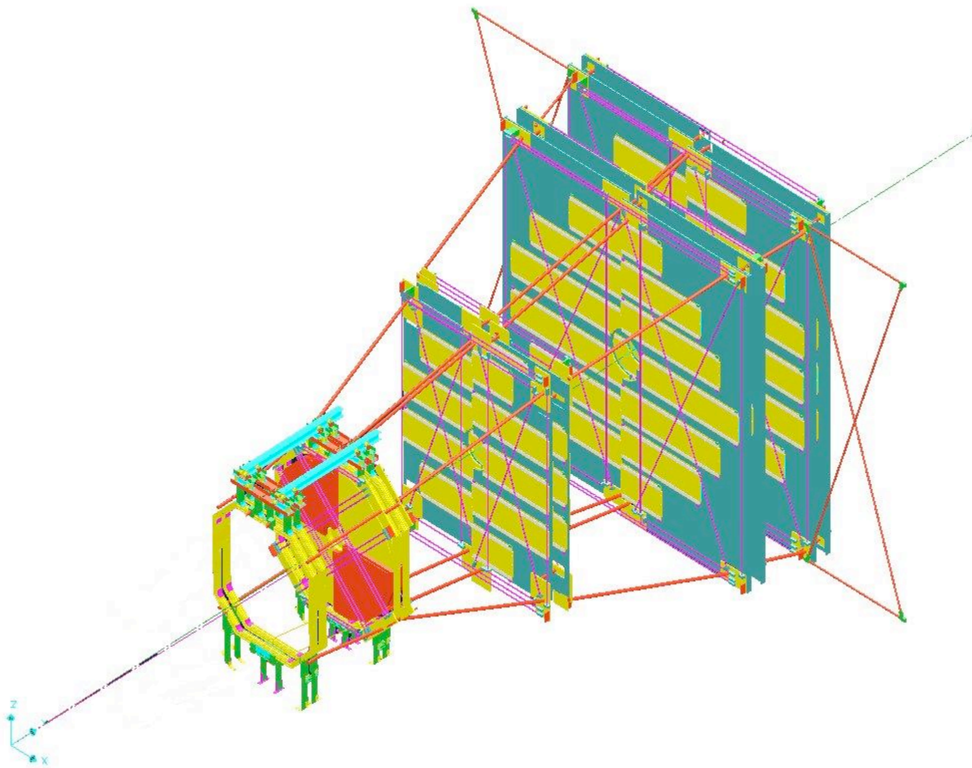


Fig. 2: The ALICE Forward Muon Spectrometer

The general philosophy of the monitoring system is that the system factorizes into two parts. The first, call the Longitudinal Monitoring System (LMS) assumes that the chamber planes are perfect and this system monitors the location of the stations relative to each other. The second part, the Transverse Monitoring System (TMS) deals with the actual shape of the detector stations. The system taken together is the Geometry Monitoring System (GMS).

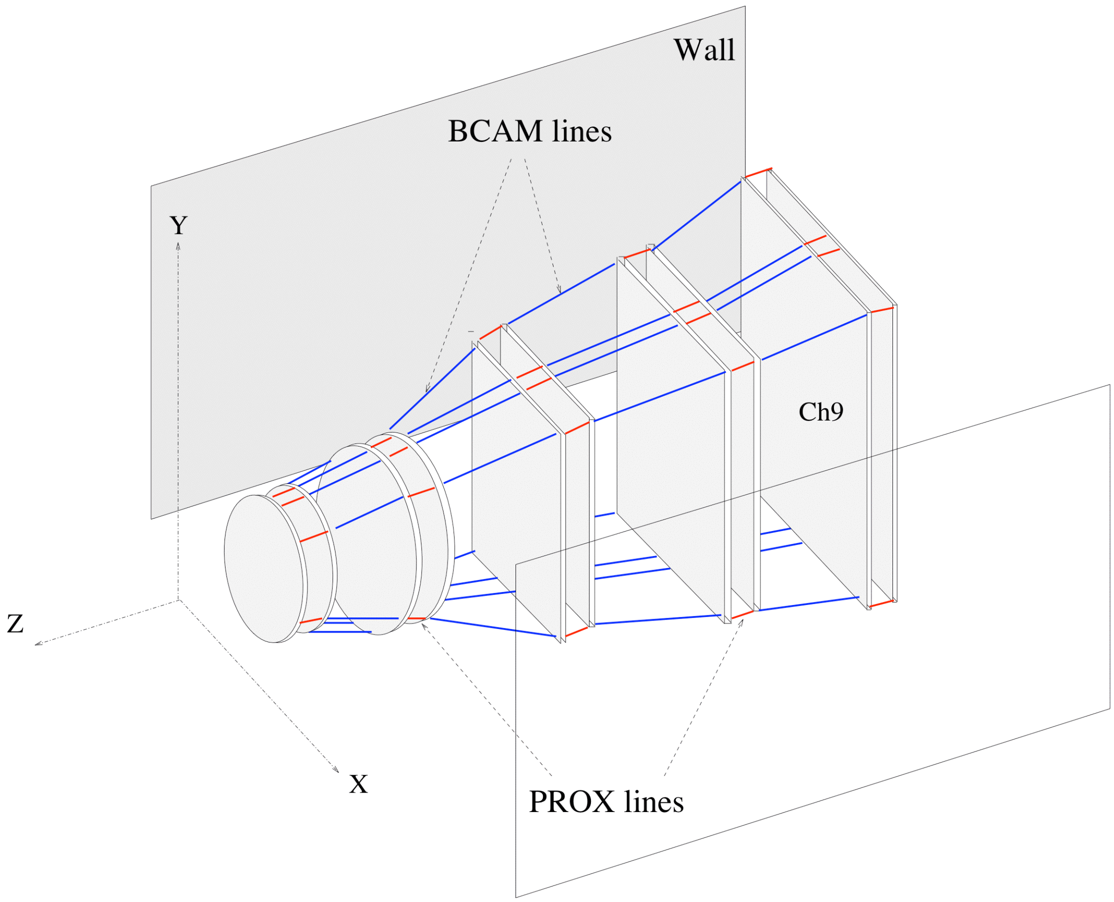


Fig. 3: The Longitudinal Monitoring System

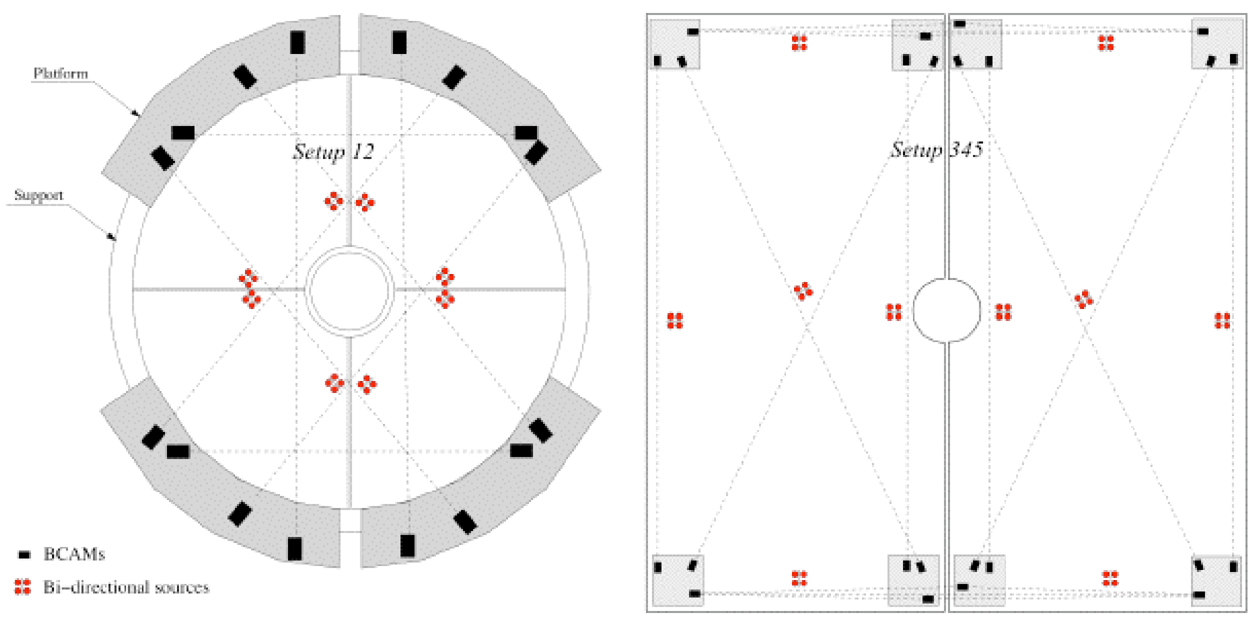
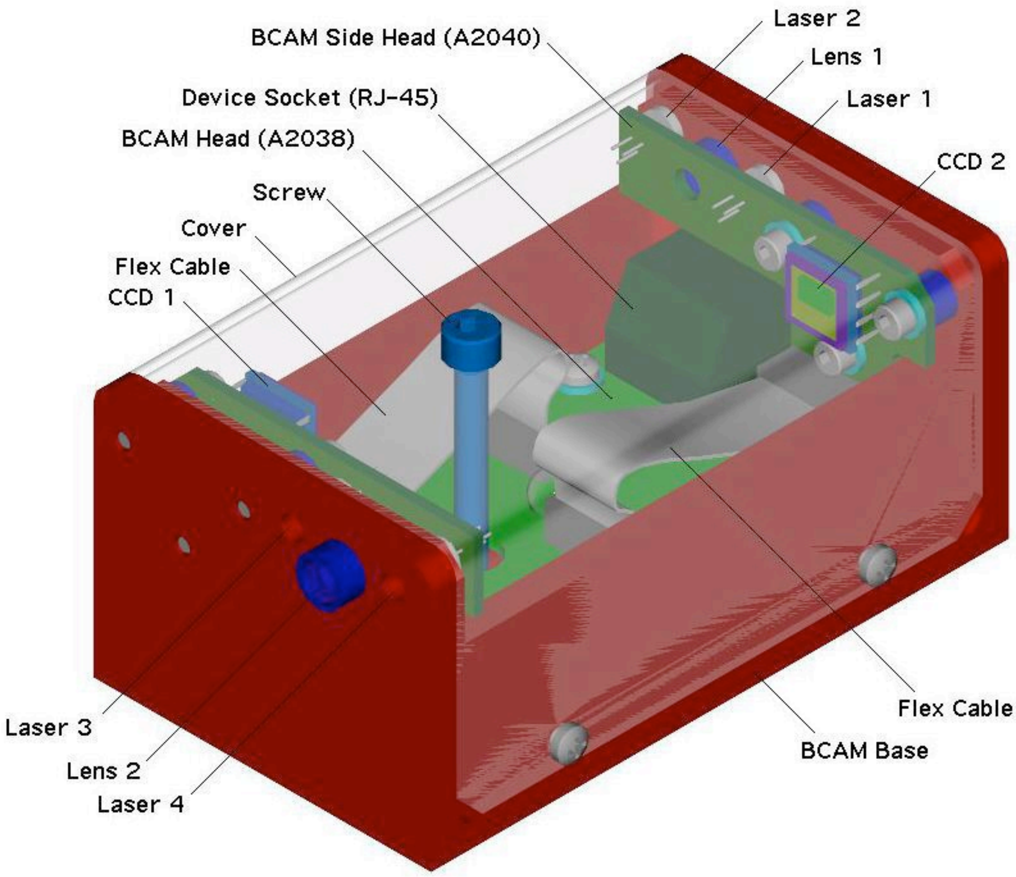


Fig. 4: The transverse Monitoring System

The principal devices selected for this system are the BCAM (Brandeis CCD Angle Monitor), generally used for long distance monitoring and a RASNIK (Red Alignment System NIKHEF) based proximity system that is used to monitor shorter distances. Data from all detectors is acquired using the LWDAQ (Long Wire Data Acquisition System) developed by Brandeis University.

The BCAM:



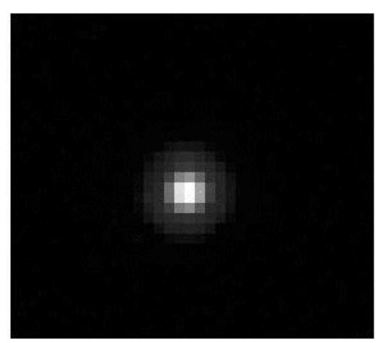


Fig 5: BCAM with a typical CCD image.

The BCAM is an electronic camera combined with two or more light sources, which looks at light sources on other BCAMs.

Figure 5 shows the BCAM. It contains two cameras and four laser-diode point sources. The figure also show a typical BCAM image, expanded so that one can see the pixels of its TC255P image sensor. The TC255P is a charge-coupled device (CCD). The TC255P image from the camera is retrieve using our Long-Wire Data Acquisition System (LWDAQ). The BCAM, combined with the LWDAQ, provides the accuracy, miniaturization, and radiation resistance appropriate for the LHC experimental environment.

For long distances, the intrinsic accuracy of our BCAMs is limited by atmospheric refraction, not by the instrument itself. The monitoring system absolute accuracy, however, will be determined by our measurement of their mounting platforms, and upon our calibration of the BCAMs themselves. Used in relative mode, where the initial system is first determined with straight tracks taken in a magnet-off condition. The deviations from that condition are followed relies only on the intrinsic accuracy of the devices and robustness of the system design.

The BCAM uses two visible laser diode light sources mounted in the camera chassis and four lasers for the bi-directional version of the BCAM. They are near-ideal point sources, in that their emitting surface is tens of microns across. They are bright and they are visible, which makes diagnosis of BCAM problems far easier than if we were to use IR LEDs. They mount directly into an anodized aluminum chassis, and by construction are within one hundred microns of their nominal positions.

The Proximity Sensors

For the short layer-to-layer distances the BCAM is not appropriate but the RASNIK system is ideal for this application. A single tube containing both the lens and CCD is attached to one layer. The lens/CCD system focuses on a mask with coded squares attached to another layer. This is done at the four corners of the layers so that the positions can be reconstructed.

A perceived limitation of the proximity sensor is that the chessboard would not remain in focus over its likely range of motion along the axis. We showed that by placing a two- or three- millimeter aperture in front of the lens, this dynamic range is increased to several centimeters, sufficient for this purpose. With the aperture in place, one can monitor the displacement of the chessboard transverse to the RASNIK axis with a resolution better than 10 microns. The RASNIK is intrinsically a 1 micron instrument, the principal error is generated by the ability to remove and replace the instrument precisely. In relative mode the 1 micron accuracy is easily achieved.

The lens and CCD have a fixed relationship so that the magnification is a direct measure of the distance from the MDT to the alignment bar. By measuring the magnification, a longitudinal displacement of the layers can be measured. The intrinsic precision of the camera/mask system transverse to the camera axis is about 1 micron.

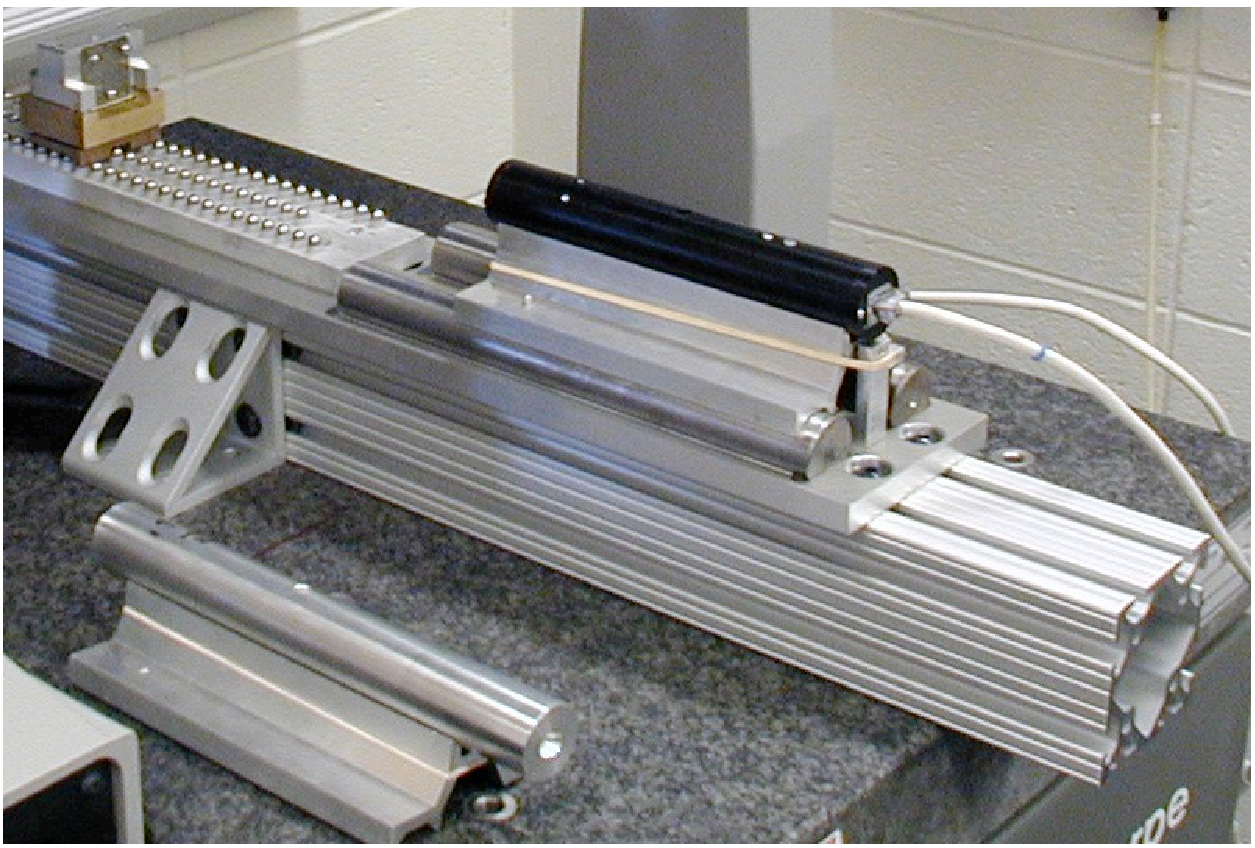


Fig 6: Proximity Camera on Calibration Stand

Test beam measurements by the ATLAS experiment have shown no evidence of any internal drift of the system over time periods appropriate to the test beam (a few months). This is reasonable since by design the detector resolution depends only on the mechanical properties of the devices such as the pixels of the CCD or the etched RASNIK masks. The CCDS are read out directly and do not go through conversion to video signals and back to digital. It is not dependent on calibration constants of amplifiers.

Long-Wire Data Acquisition System (LWDAQ)

The LWDAQ is a general-purpose data acquisition system designed for use with the above devices [link LWDAQ documentation]. The LWDAQ is resistant to >30 krad ionizing radiation, and >10^13 1-MeV eq. n/cm^2 neutron radiation. It can retrieve twenty images per second from a camera at the other end of a 100-m cable. Continuous development over the last four years has brought about the evolution of the LWDAQ designs, which are robust, convenient, and inexpensive.

The LWDAQ Driver with VME Interface can run a LWDAQ out of a VME crate. There also exists a LWDAQ Driver with Ethernet Interface which can run a LWDAQ over TCP/IP. The Ethernet version is more popular in laboratories, while the VME version will be used in large data acquisition systems. The LWDAQ driver has 10 sockets. The LWDAQ multiplexer provides ten branch sockets. Thus a single driver can operate up to 800 devices, where each device may have multiple functions.

Comments and Recommendations

1) The layouts of the LMS and TMS are sensible and simulation shows that the systems give sufficient accuracy for the goals of the experiment. The TMS however makes the assumption that the major problem that has to be corrected by the system is a long wavelength variation of the shape of the chamber. This is a reasonable assumption but should be checked by a survey of the chamber shape when mounted in the final design of the mounts and in all geometric orientations.

2) The external links at station 9 should be anchored into the walls in the same fashion as the survey group anchors their survey monuments into the wall.

3) Although underground caverns are relatively stable for temperature, the temperature of all major components should be monitored to insure this is the case. If the temperature is not stable, then corrections will have to be made in the monitoring software to account for variations.

4) The system exhibits graceful degradation with instrument failure. This indicates a robust design.

5) Special attention should be placed on the design and mounting of the BCAM base plates. Care should be taken so that shear is not transmitted to the plate when it is mounted. The plate itself should be sufficiently stiff and stress free that distortions are not induced in mounting or creep in over time.

6) The location of the survey targets on the BCAM base plates should well known with respect to the BCAM kinematic mount. The necessary precision can be achieved by careful survey of target and BCAM mounts by the metrology department before the mounting plates are installed.

7) A recommendation for the design of the survey target holders when doing photogrammetry shown in the following figure.

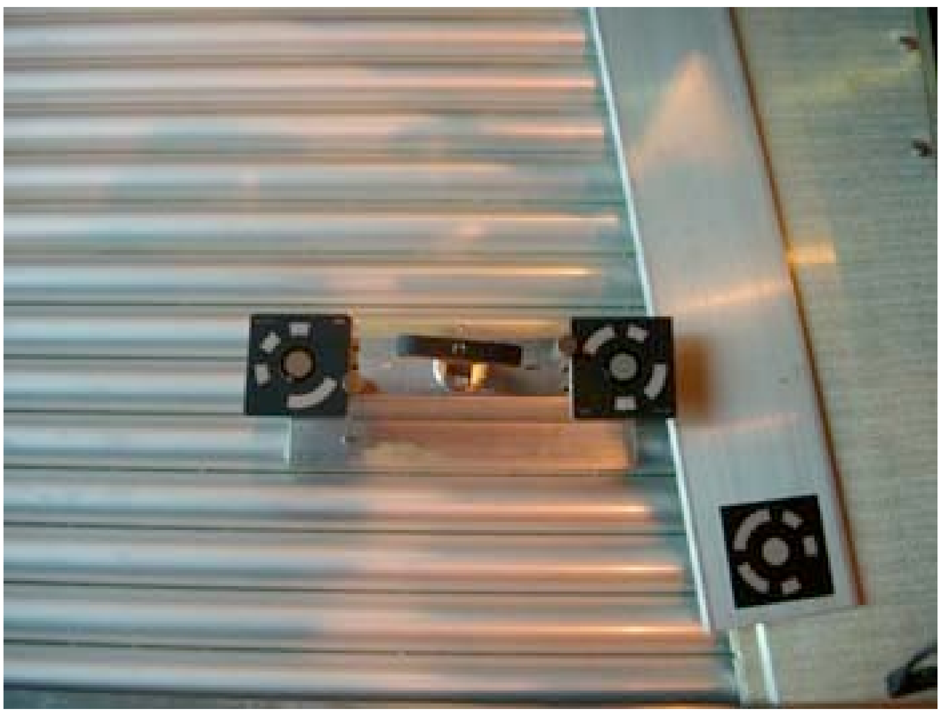


Fig 7: Photogrammetry Target for Proximity Camera Mount.

8) That all sensors be installed with torque screwdrivers set to 20 in-oz (14 cNm). This will insure that all cameras and their replacements set in the same way in their mounts.

9) Special care that sensors are not placed near unusual hot spots and the air circulation is good for all optical lines. This is important to reduce local temperature gradients that can deteriorate measurements.