Simplified Hexapod Alignment for GRETINA

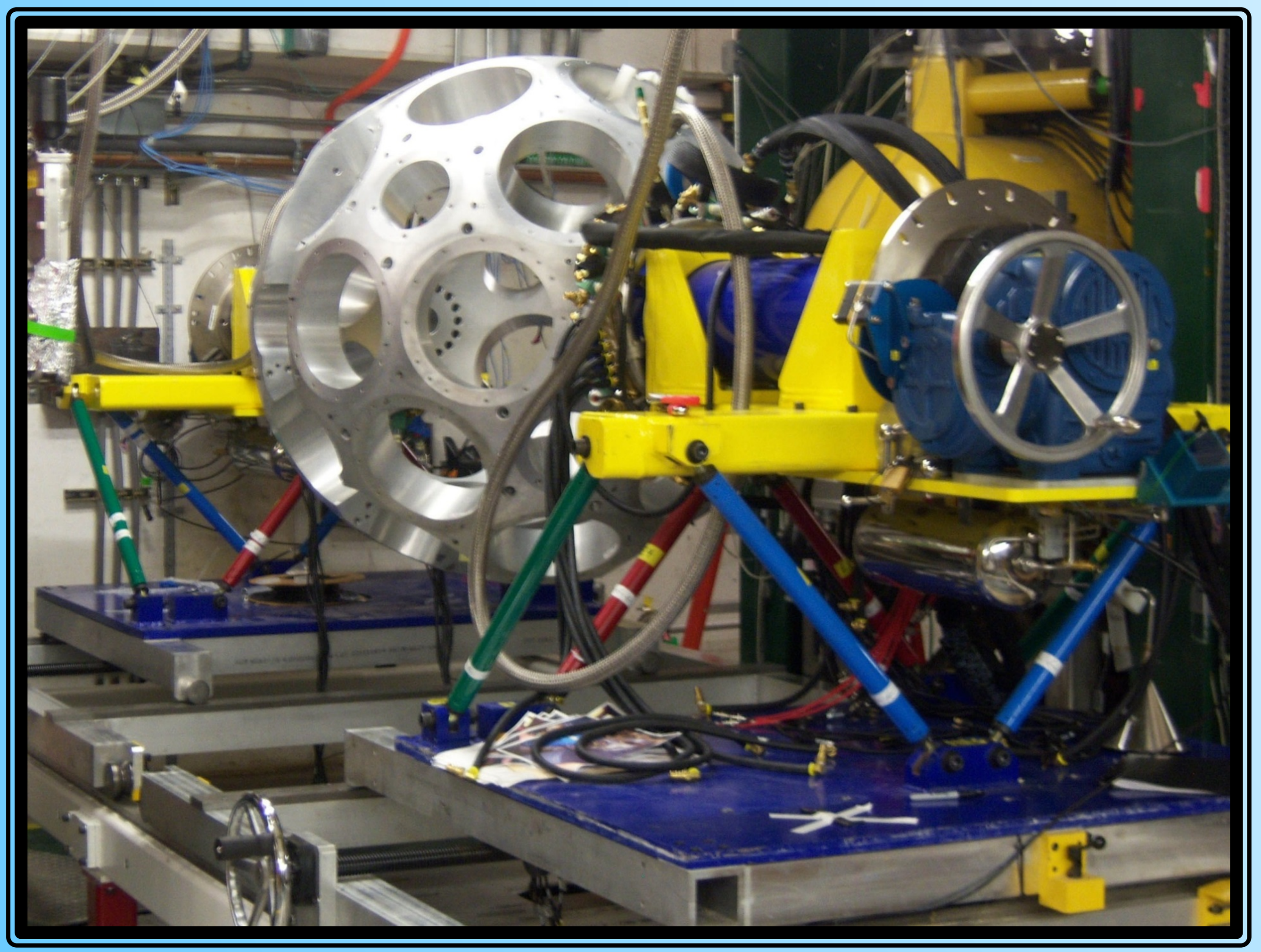
William G. Jansma, John Rohrer, Shaofei Zhu
Argonne National Laboratory, Argonne, Illinois, USA

Abstract

GRETINA is a ¼ scale diminutive version of the proposed Gamma-Ray Energy Tracking Array (GRETA). This new type of gamma-ray detector is designed to study the structure and properties of atomic nuclei. It uses large crystals of hyper-pure germanium and is the first detector to use the concept of gamma-ray energy tracking.[1] In August 2013 the GRETINA detector was delivered to the Argonne Tandem Linac Accelerator System (ATLAS) for an experimental run. GRETINA consists of two machined aluminum hemispheres in which several gamma ray detectors are mounted. Each hemisphere is cantilever-mounted to a manually operated hexapod alignment frame. Only one hemisphere is in use at Argonne. A direct, simplified hexapod alignment method utilizing a laser tracker and optimally placed fiducials is presented.

Background

A hexapod is a parallel kinematic device that provides alignment capability in six degrees of freedom (X, Y, Z, pitch, yaw & roll). Alignment of the GRETINA hemisphere with respect to the accelerator beam is accomplished by manually rotating the six hexapod struts to adjust their length. A procedure to align the hemisphere was provided, and included a spreadsheet program that computes the direction and degrees of rotation to be applied to each hexapod strut based on the transformation parameters of a least-squares fit between the actual and ideal positions of the hemisphere. Alignment of the hemisphere may be accomplished using this method; however, the process cannot be monitored in real time. The entire procedure must be executed before the results are known, and if a blunder is made it cannot be detected until the procedure has been completed. In addition, several iterations of the entire procedure are necessary to achieve the alignment tolerance of +/- 0.25 mm, making it time-consuming. Initial attempts to align the GRETINA hemisphere using the provided procedure were unsuccessful, and it was decided to try a more direct approach.

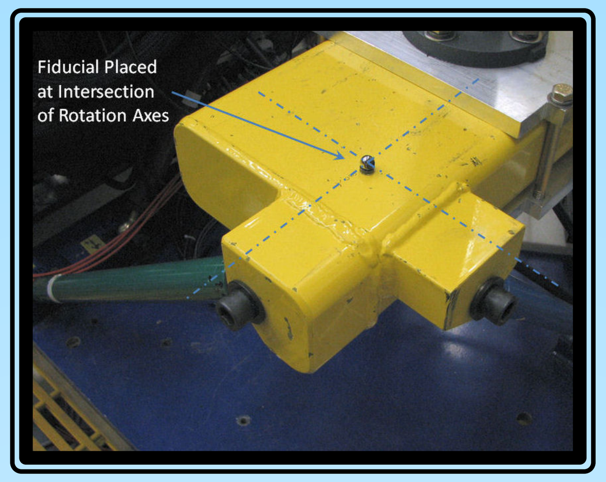


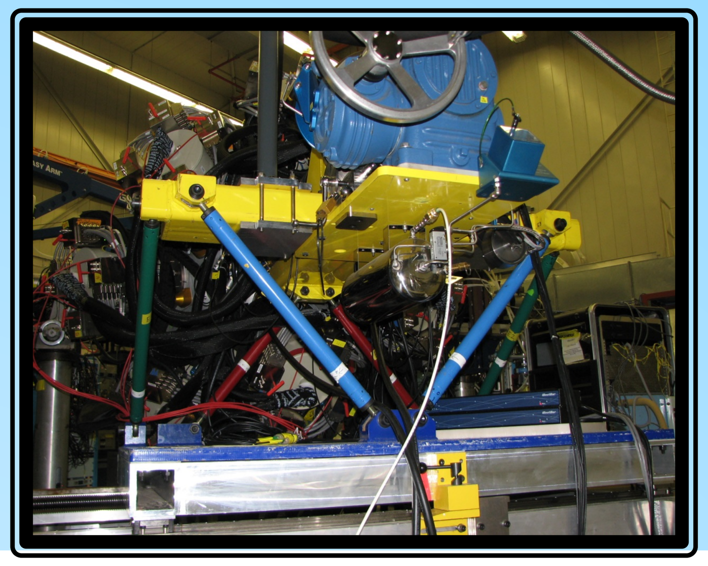
GRETINA prior to detector installation

Direct Alignment of GRETINA

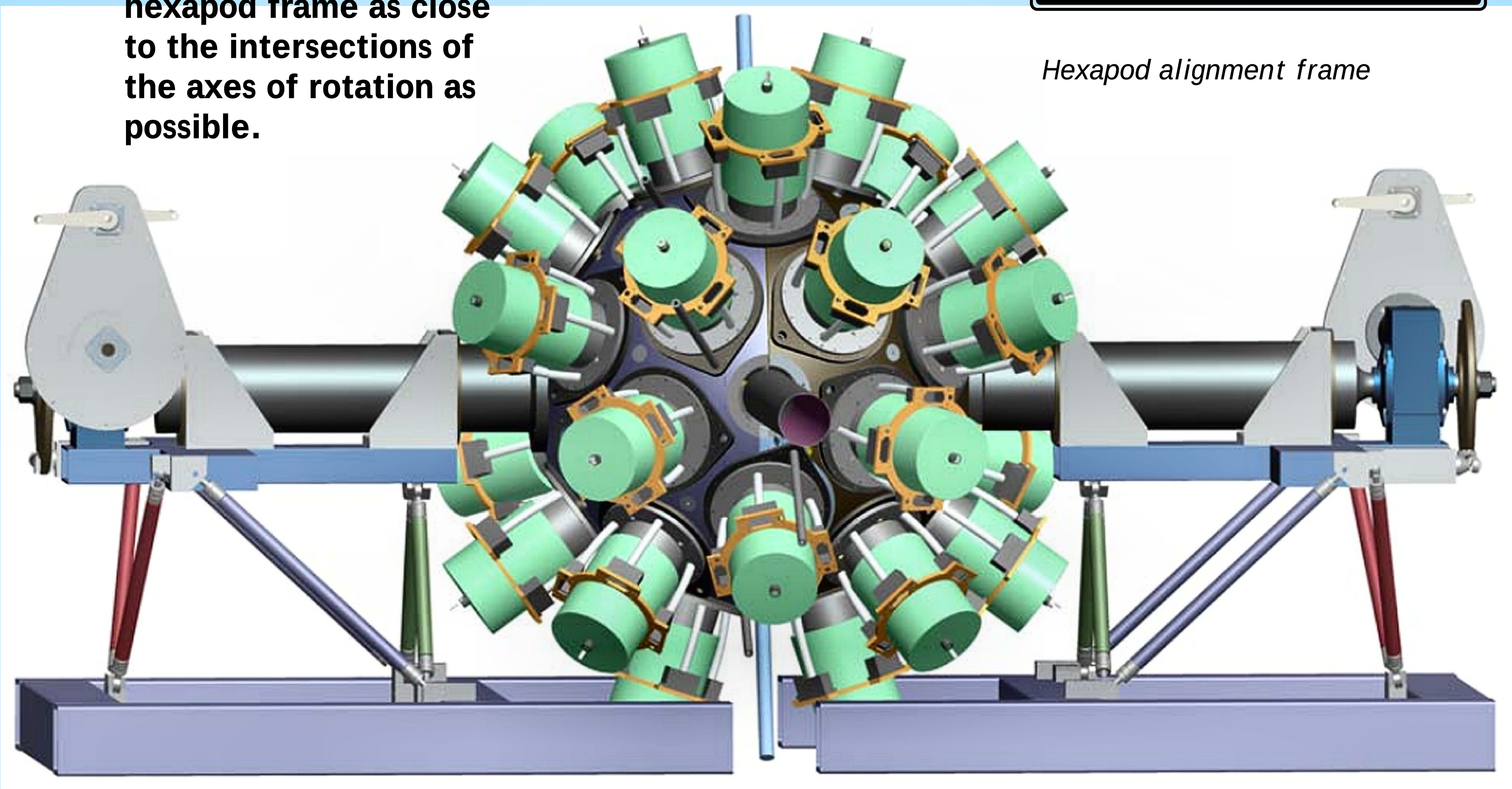
The direct approach to aligning the GRETINA hemisphere involves placement of fiducials at optimum locations, and utilizes the capability of the laser tracker to perform as a 3-D indicator.

- **Optimum fiducial placement in order to minimize alignment backlash is the key to direct hexapod alignment. Four new fiducial points were added to the upper hexapod frame as close to the intersections of the axes of rotation as possible.**



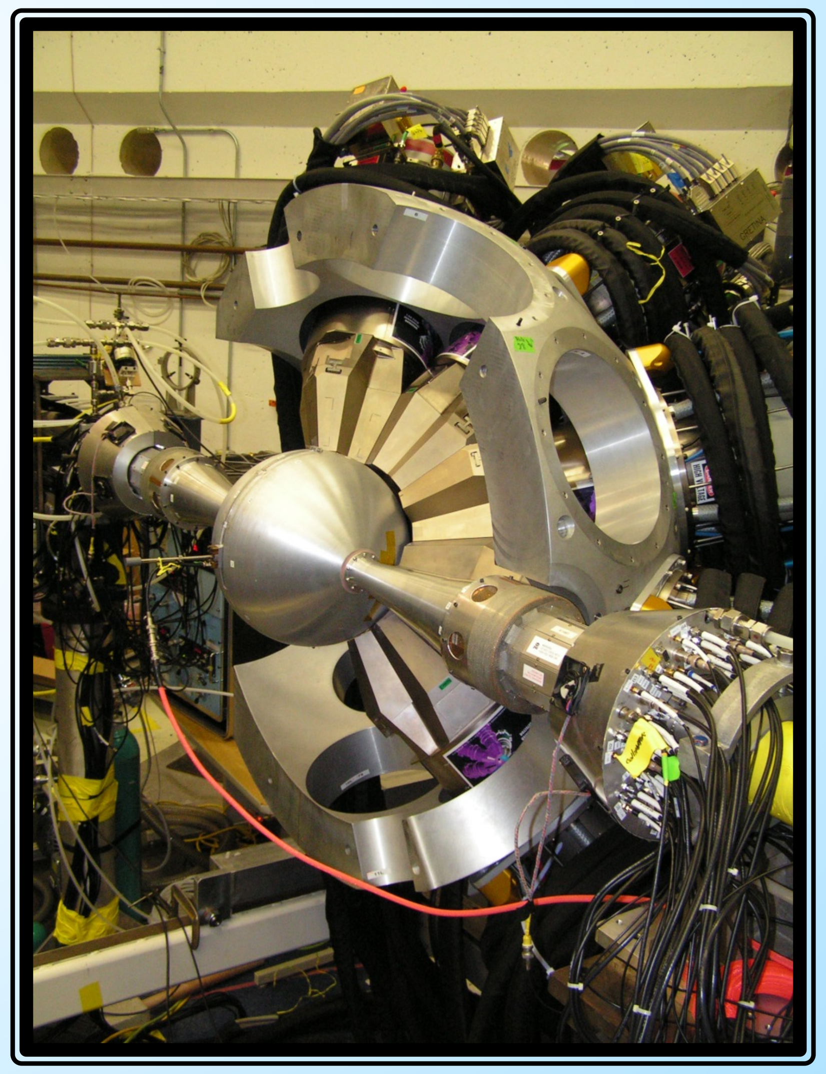


Hexapod alignment frame



- **Three-dimensional coordinates of the new fiducials were measured within the GRETINA hemisphere coordinate system using a Leica LTD500 laser tracker, and saved to a reference file.**

- **The laser tracker was oriented within the beam-line coordinate system. Using the measured reference coordinates and the laser tracker's 3-D indicator capability, the hemisphere was aligned directly into position by adjusting the lengths of the hexapod struts while monitoring the position of each new fiducial in real time. The detectors were mounted in the hemisphere after initial alignment, and the procedure was repeated, as the additional load introduced by the detectors changes the relationship between the hexapod frame and the hemisphere.**



View of GRETINA Hemisphere showing equatorial plane and detector array

Alignment Results

Optimum fiducial placement limited alignment backlash to less than 0.5 mm, and only two adjustment iterations were necessary to bring the hemisphere into alignment with respect to the beam.

The results of the final least-squares transformation between the ideal and aligned positions are as follows:

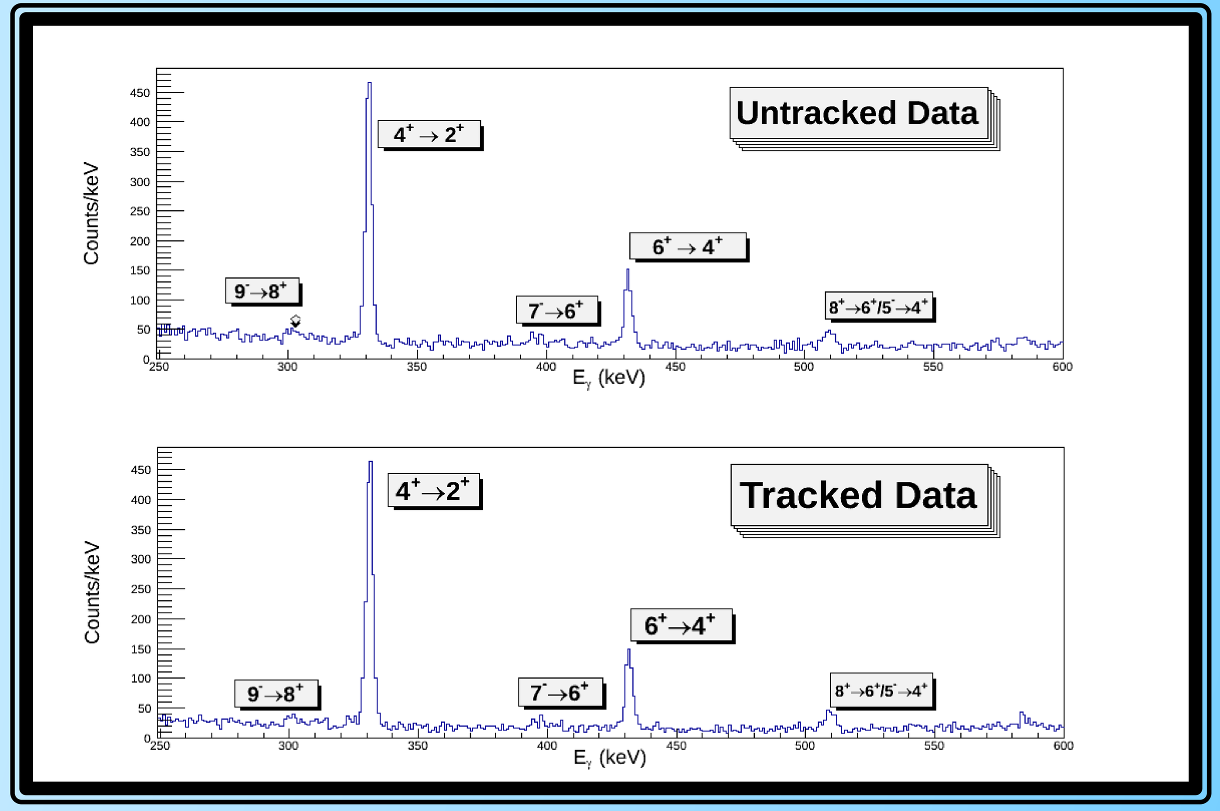
GRETINA Hemisphere Final Position - Ideal vs. Aligned			
dX	-0.13 mm	rX	0.0011°
dY	0.13 mm	rY	0.0036°
dZ	0.05 mm	rZ	-0.0049°

An independent verification using a precision optical tooling transit indicated that the equatorial plane of the hemisphere was aligned to within 100 microns both vertically and parallel to the beam axis.

Experimental Results

The alignment results for the GRETINA detector are validated by the experimental results.

The difference between the tracked data versus the untracked data is in the background level. There is about a 40% reduction of background in the tracked data, which enhances the peak to background ratio. This enhancement is a result of the proper alignment of the detector array relative to the target position.



Conclusion

Real-time, direct alignment of the GRETINA hemisphere utilizing a laser tracker and optimally placed fiducials on the hexapod alignment frame simplifies the process, allowing precise alignment of the hemisphere to be achieved in less than 3 hours with only two adjustment iterations and resulting in significant savings of time and effort as compared to the provided procedure.

References

1. https://commons.lbl.gov/display/nsd/Projects

The 13th International Workshop on Accelerator Alignment
October 13 - 17, 2014 - IHEP - Beijing, China

* Work supported by U.S. Department of Energy, Office of Sciences, under Contract No. DE-AC02-06CH11357