An optical sensors for the alignment of the Atlas muon spectrometer

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Abstract: In the Atlas muon spectrometer [1] the alignment system should control the spatial position of the muon chambers with an accuracy of 30 µm and 200 µrad for a range of ±5 mm and ±10 mrad. The alignment device described in this paper, called Praxial, fulfill these requirements.

Keywords: alignment, muon, optical system, absolute positioning

Alignment requirements for the Atlas muon spectrometer:

We have developed at Saclay and Nikhef various alignment devices based on optical elements in order to perform the alignment of the complete Atlas muon barrel spectrometer. The goal is to control the spatial position of all the muon chambers with an accuracy of 30 µm and 200 µrad for a range of displacements of 10 mm and 10 mrad. This challenging accuracy is required in order not to degrade the reconstruction of the muon momentum mainly above 100 GeV/c.

The Praxial sensor:

Most of the alignment devices are based on an optical system called Rasnik [2] working with a coded mask/screen seen through a lens by a CMOS camera. The associated software provides the reconstructed position on the mask, as seen by the camera, with an accuracy of ~1µm. Optical sensors based on this principle and assembled in ad-hoc layouts are used to reconstruct the *absolute* spatial positions of two adjacent Atlas chambers.

In particular, the "Praxial" sensor (Fig.1), one of the key element of the alignment, works with two crossed Rasniks where the optical elements of each system seat on both supports (each on a different muon chamber): the camera and the lens on one support and the corresponding mask on the other support (and vice versa for the second optical system). With this set-up and after a calibration procedure described below, the six degrees of freedom of one support with respect to the other are completely constrained.

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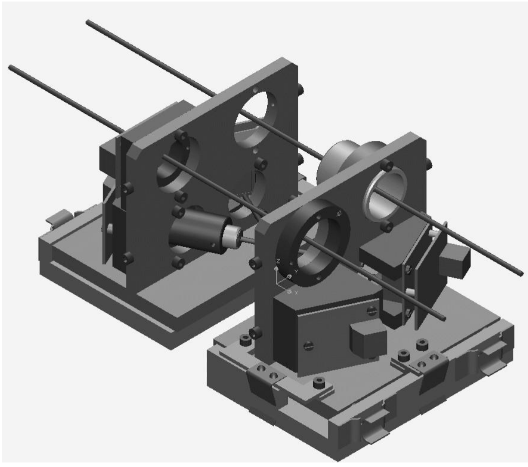

Fig. 1: The “Praxial” sensor is made of two separate elements and uses two crossed Rasniks at their “lower” level. The upper part of the sensor corresponds to the “Axial” alignment and is used to unite a complete layer of six chambers.

Calibration of the Praxial sensor:

To calibrate these sensors two by two at the 30μm and 200μrad levels we have developed and built a calibration set-up and the corresponding software working on the following principle (Fig. 2):

i) one of the two Praxial supports is moved about one hundred times with respect to the other one,

ii) each displacement is recorded by precise, <5 μm, mechanical probes,

iii) both optical systems used in the Praxial are recorded for all displacements,

iv) finally a fit is performed in order to adjust each optical element position (lenses, cameras and masks) in order to be compatible with both optical system outputs and with the known mechanical displacements.

Simulations have shown that, after the fit procedure, the final precision on the absolute space position of one support with respect to the other one can be of the order or even below 30 μm for a range of ±5 mm and ±10 mrad.

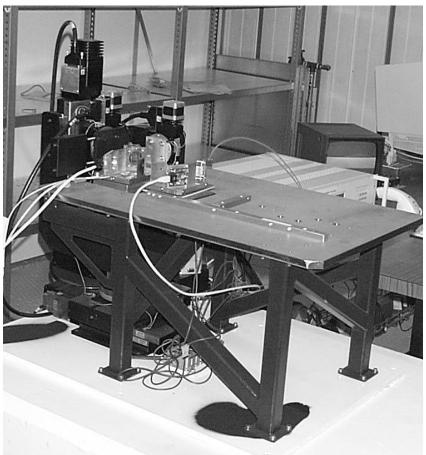

Fig. 2: The “Praxial” sensor calibration bench. The black elements on the left of the picture are the 6D micrometric tables (Δx, Δy, Δz, θx, θy, θz) used to move one support with respect to the other one. The mechanical probes used to measure accurately the displacements are located below the aluminum plateau.

Final control of the calibration:

We have also developed a specific bench for the calibration of the upper part of our sensors: the "axial" sensor.

In order to check all these calibrations, both software and hardware approaches are used. We thus have designed a standard Praxial (see Fig. 3) for which each optical element position is known with a precision of the order of 20 μm (except the lens position along its optical axis). To obtain this precision we use an optical microscope to locate all individual elements on their aluminum square and we calibrate each Rasnik independently.

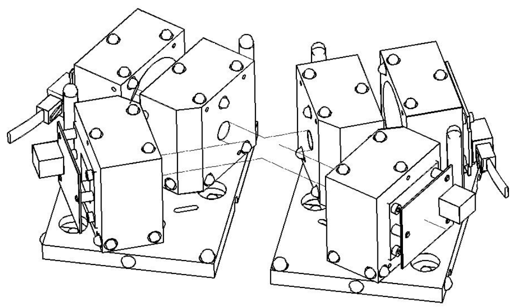

Fig. 3: Drawing of the "standard" Praxial. Each optical element is located on an aluminum square in order to be calibrated one by one before their installation on the support.

In addition, a complete test bench to check the alignment devices working on the same line in the Atlas experiment (up to 12 elements on 15 meters) is considered as the final check of the overall calibration procedure. It will use precise tilt-meters, auto-collimator and optical detectors in order not only to check the calibration but also to verify that there is no error and no bias propagation along the line.

References:

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