DESY F-1_ 3

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RECONSTRUCTION OF THE OPTICAL COORDINATE SYSTEM FOR BUBBLE CHAMBERS

G. Wolf

For a geometrical reconstruction of the bubble chamber photographs the relative positions of cameras and fiducials have to be known. A direct precise measurement of the camera and fiducial coordinates seems not possible for low temperature chambers (such as a hydrogen bubble chamber) during normal operation. Usually the relevant coordinates are therefore measured at room temperature and then corrected for thermal contraction. Thereby, however, uncertainties are introduced

- the behaviour of the bellows at the chamber windows (carrying the fiducials) is unpredictable. The resulting inaccuracies of the distance (z-direction, see fig. 1) between cameras and chamber windows are of the order of 0.5 cm.
- In addition the chamber windows change position in xy direction during the cooling-down period. Typical rotation angles and translations in the xy plane are (5 - 10)mrad and (0.1 - 0.5)cm respectively.

In the following a method is described which overcomes these difficulties. The relative camera and fiducial coordinates are obtained

directly from the bubble chamber photographs and are hence determined for the operation status of the chamber. As all information is contained in the film, changes in the optical coordinates are easily dealt with during a run (e.g. because of warming up the chamber). In addition misalignments of the optical components can be detected.

The method requires fiducial marks on both sides of one of the chamber windows (see fig. 2). The relative position of these fiducials, inclusive the thickness of the window, can be measured with great accuracy. (This can be done at room temperature). By correcting the thermal contraction we know the relative positions of fiducials in two different xy planes with great accuracy and the operation temperature of the chamber. The positions of these fiducials on the film are measured in different views (i.e. in the projections of the different cameras) on digitized measuring machines. The absolute scale of the film coordinates is irrelevant. These measurements and the known fiducial coordinates on the glass fix the x,y,z position of the cameras.

In case there are additional fiducials on the other chamber window their space coordinates can also be determined from their film coordinates. In this way, for example, the depth of the chamber can be measured.

Apart from obvious factors the accuracy of the method depends on the thickness of the fiducial window and on the number and positions of the fiducials: The accuracy is proportional to the thickness of the window; at least four fiducials on each side of the window are recom-

mended. These fiducials should be widely spaced and visible in all views.

A FORTRAN program named BLASYS has been written to reconstruct the optical coordinate system in the described manner.

The input consists of:

1. the space coordinates of the fiducials;
2. known optical constants, such as refractive indices of the chamber windows;
3. starting values for the camera coordinates and for other parameters to be fitted;
4. film coordinates of the fiducials; in case there are several measurements, the film coordinates will be averaged.

The parameters to be fitted are determined using a least squares method which optimizes the agreement between the fiducial measurements on film and in space (the fit is done with MALIK, a subroutine written by Grard, UCRL 10153).

BLASYS has been written in such a way that a change in the choice of the parameters (camera coordinates, thicknesses of media, refractive indices, etc.) is easily accomplished.

BLASYS is used together with the 84 cm hydrogen bubble chamber at DESY. An idea of the accuracy achieved with this method may be obtained from table I. There the results for one of the exposures of the 84 cm chamber are shown. The relevant chamber dimensions can be read off from fig. 3. The errors given have been determined in several ways and are believed

to be realistic. The parameters to be fitted have been

1. the x,y coordinates of three cameras;
2. the rotation angle and the x,y translations of the front window;
3. the distance: focus - front glass
4. the chamber depth.

In order to save computer time in a first step these 11 parameters have been successively fitted using the results of the previous fits for the determination of the next set of parameters. In this way approximately correct parameter values are obtained which can be used as starting values for a final fit where all parameters are fitted simultaneously.

Table I: BLASYS results on the determination of the optical system of the 84 cm chamber in the June 1966 exposure.

Input	number of fiducials used on the back glass	
	a) inside chamber	6
	b) outside chamber	4
	number of fiducials on front glass	3
	uncertainty of the space coordinates of the fiducials	(10 - 20) μ
	uncertainty of the averaged film coordinates of these fiducials	1 μ
	(the demagnification factor: chamber → film is 15)	

Table I cont'd

Results

rms deviation of fiducial coordinates on film:	
measured / compared to expected from fit (using the space coordinates of the fiducials and the fitted parameter values)	$\sigma_x \simeq \sigma_y \simeq 17\,\mu$
rms deviations of camera coordinates	$\sigma_x \simeq \sigma_y \simeq 0.02$ cm
distance: focus - front window	108.312 ± 0.03 cm
chamber depth	39.764 ± 0.01 cm

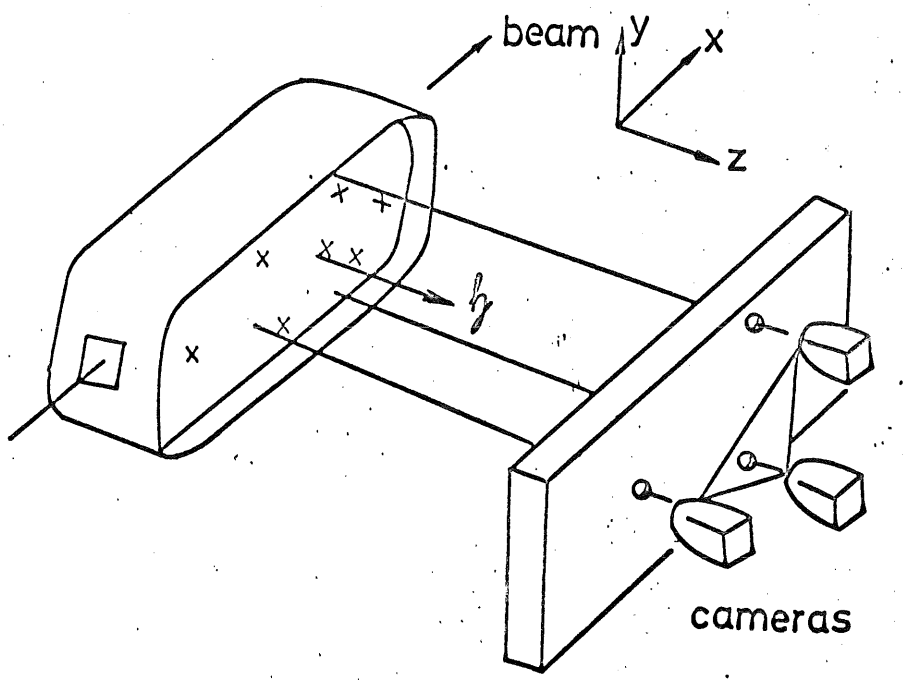


fig.1

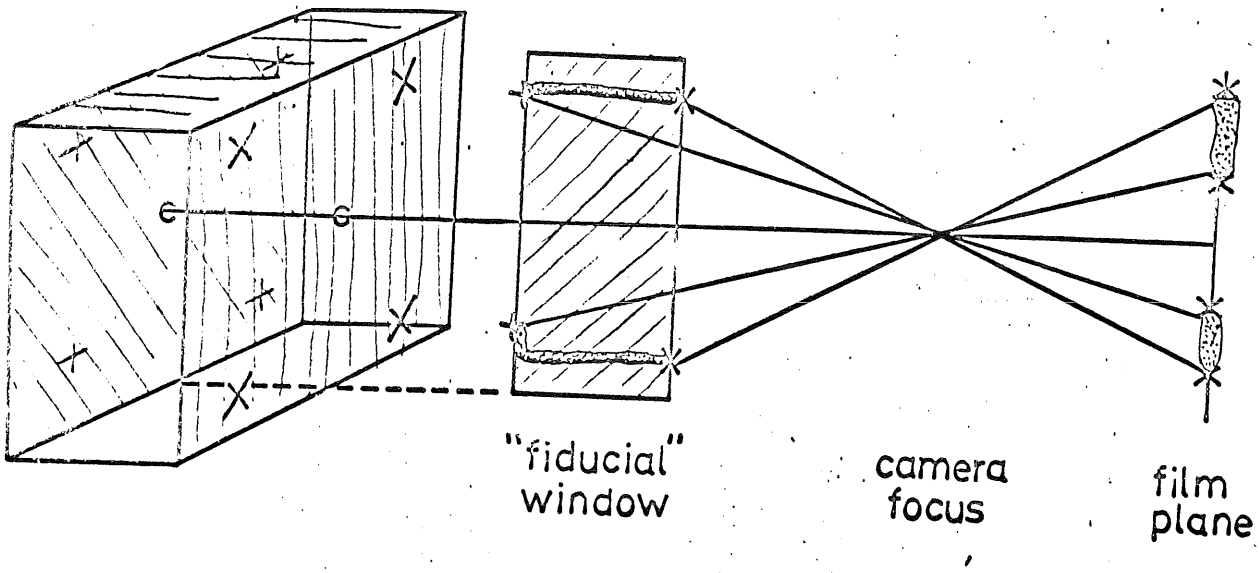
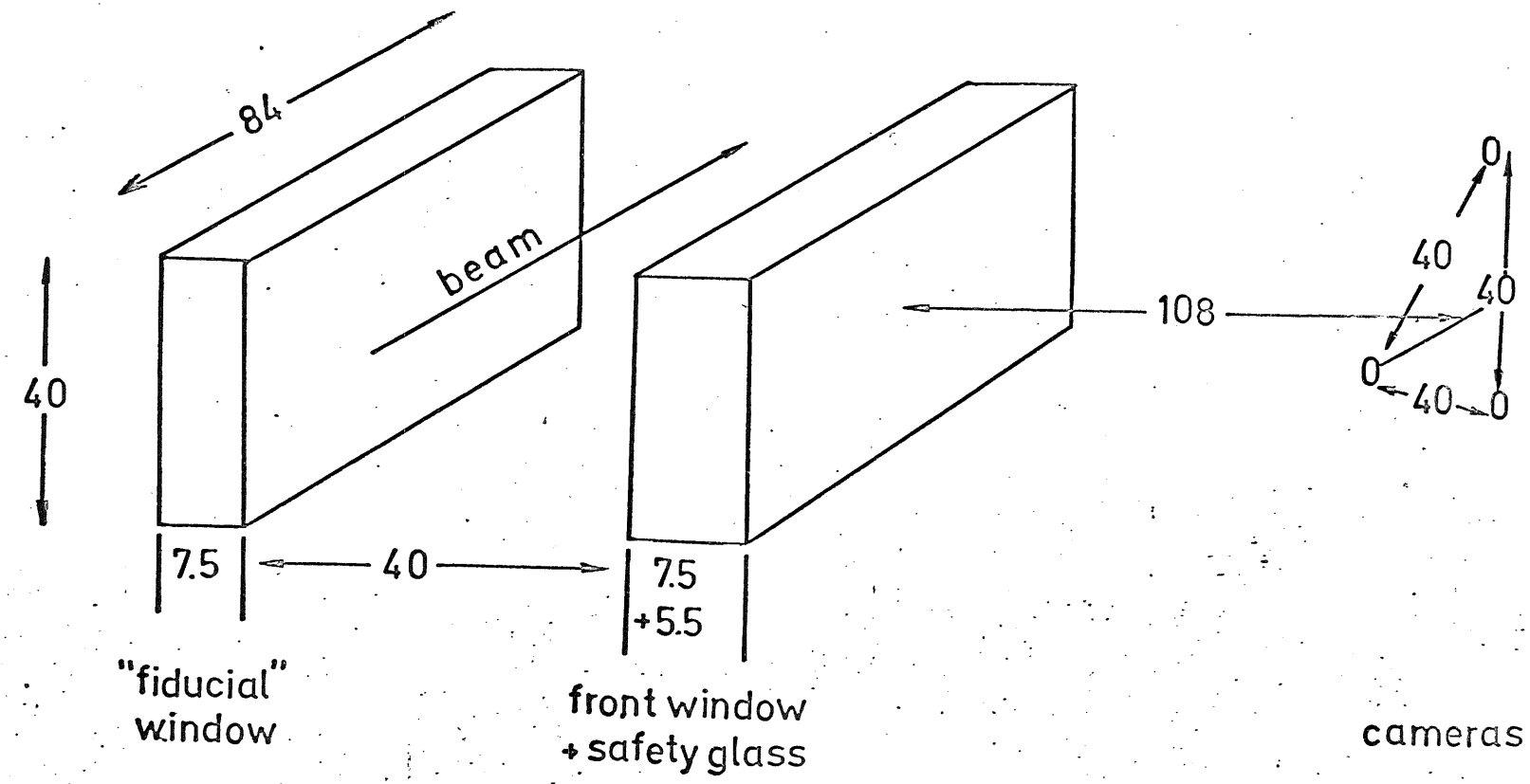


fig.2



The numbers give the dimensions in cm

fig.3