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Performance test and Commissioning of the Experimental Target Station T24

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1. Introduction

In this note, we summarize the results obtained during the commissioning of the Experimental Target Station T24, installed in the North Area Hall EHN1. The target T24 which is fed by the primary proton beam P4 is specially designed for the production of the high energy neutron beam N4.

The tests were performed on the 13th and 20th October, 1978. During the measurements the target was irradiated by a slow extracted proton beam of 400 GeV/c, a spill duration of about 0.5 s, and an intensity of a few 10^{10} ppp.

These tests verified the proper functioning of all hardware and software associated with the target station. In particular, the correct acquisition of the upstream and downstream secondary emission monitors was checked and their relative alignment with respect to the target was determined. Furthermore, the secondary particle yield measured with the monitor downstream of the target, was compared with the combined neutron + photon fluxes as measured with a counter of the NA6 experiment.

2. Design requirements and layout

The Experimental Target Station T24 is designed to operate in a slow extracted proton beam of 400 GeV/c, about 10^{11} protons per pulse (ppp) and a beam diameter of about 2 mm. The neutron beam N4 is produced in T24 from the protons supplied by the P4 beam. This beam is the continuation of the primary protons which have not interacted in the target T2 of TCC2.

The layout (side view) of the Target Station T24 is shown in Fig. 1 a. The target container and the adjacent upstream (TBIU) and downstream (TBID) beam monitors are completely surrounded by a cast iron shield. The top shielding is placed on rails, so that it can be opened for the replacement of the target container or beam monitors.

The beam monitors and the target container are suspended via rigid stainless steel tubes from a common triangular frame mounted on top of the shield. This frame was used, prior to installation, to align the target and the two monitors TBIU and TBID on a common, well defined axis. Thereafter, this axis was aligned with the nominal beam axis of the P4 beam in EHN1.

The targets

The target container (see Fig. 1b) houses two "pencil-like" targets with a length of 400 mm and made from beryllium respectively aluminium (see Table 1). Each target consists of four rods and each rod is mounted on an individual support structure consisting of two annular frames rigidly connected by a horizontal bar. A precision hole equal to the target diameter is punched into the aluminium foil of 25μ thickness which is clamped into each frame. Thereafter, these holes serve to position the rods. The four individual rods of a target are aligned within an accuracy of ± 0.05 mm. Since each rod is supported by two foils of 25μ thickness, the total "undesired" support material within a diameter of Ø 40 mm around the target amounts to 0.2 mm of aluminium only.

Target head	Material	Length (mm)	Diameter (mm)
T24/0	no target (beam passage free of material within a diameter of Ø 70 mm)		
T24/1	Be	400	Ø 2
T24/2	Aℓ	400	Ø 1.5

Table 1 - Target heads for T24. T24/0 is for the unobstructed passage of the primary proton beam P4 and for the alternate use of this line for H4/E4 beam.

The position T24/0 without target and a diameter free of material of 70 mm diameter is provided for the unobstructed passage of the primary proton beam and for the alternate use of this line for the H4/E4 beams. The targets T24/1, T24/2 and the empty position T24/0 are selected by a vertical displacement of the target container. The indexing mechanism used for the selection guarantees a reproducibility in target positioning of ≤ 0.02 mm.

The target is cooled by natural air convection only, since under this condition the beam induced average temperature rise in the target is $\leq 10\ ^{\circ}C$ per 10^{11} ppp.

The beam monitors

Fig. 2 gives a schematic layout of the target and the secondary emission monitors TBIU and TBID. The incoming proton intensity is measured via the charge which is created in the foil BSI-1 during the traverse of the protons.

The horizontal (BSP-H) and vertical (BSP-V) split-foils serve to steer the incident proton beam on the target axis. The accuracy of the proton beam positioning via the split-foils of the TBIU is about 0.1 mm.

The halo detector BSH-1 consists of a foil with a circular hole of 2 mm diameter, adapted to the waist of the proton beam. In the case where the target T24/1 is in operation, the BSH-1 measures the flux of those protons which are not intercepted by the target.

A BSH signal which becomes comparable to the BSI-1 signal indicates that either the beam has drifted away from the target axis or the beam waist is blown up. The latter case is more important, since it is not necessarily detected by the split-foils.

The TBID monitor downstream of the target contains two integrating foils which measure the sum of the charged secondary particle flux from the target and the non-absorbed proton intensity. The BSI-2 and BSI-3 saturate at a particle flux above $\sim 1.3 \times 10^{12}$ respectively $\sim 1.3 \times 10^{13}$

particles per burst. For a target of about one interaction length the charged secondary particle flux is typically about one order of magnitude higher than the incoming primary proton flux. Therefore, the general quality of the targetting can be surveyed by monitoring continuously the ratio of the downstream to the upstream particle flux, e.g. BSI-2/ BSI-1, which gives directly the target yield, also called target multiplicity.

When the primary proton beam is not intercepted by the target, the horizontal (BSP-H) and vertical (BSP-V) split-foils in the TBID can be used together with the identical detector elements in the TBIU to define the horizontal and vertical angle of the proton beam with an accuracy of $\leq$ 0.2 mrad.

Moreover, as will be discussed later, the angle of the incident proton beam can be measured, although with reduced accuracy, while the beam is intercepted by a target, since the secondary beam downstream of the target (i.e. transmitted primary protons plus secondaries) is still sufficiently peaked in the primary beam direction to give a useful split-foil reading.

3. Measurements and results *)

The beam monitors TBIU and TBID, and the target selection worked properly from the beginning. The target multiplicities were measured for both heads with a proton beam well centered on the target (see Table 2).

Target head	Multiplicity	BSI-1/BSI-1
T24/0	1.0	
T24/1	8.2	
T24/2	10.5	

Table 2 - Target multiplicities

*) We thank H. Atherton for his support during the measurements

Since the direction of the neutron beam N4 is completely defined by the direction of the primary proton beam incident on T24, a good alignment of the target with the beam axis is essential, because it guaranties a maximum neutron yield combined with a small lateral source size. Therefore, the alignment of the target station with the beam axis was carefully checked in two steps.

Firstly, without placing a target into the beam, it was verified whether the axis which is defined by the horizontal (BSP-H) and vertical (BSP-V) split foils in the upstream (TBIU) and downstream (TBID) monitors, coincided with the axis of the incident proton beam, when the latter was well centered on the upstream split foils. For this purpose, a parallel displacement of the proton beam was made in both the horizontal and vertical direction, during which the split foil signals were recorded. The results of these scans are shown in Fig. 3. In the horizontal plane the TBID split foil centre is separated by 0.13 mm from the beam axis which corresponds to a difference in angle of 0.15 mrad. In the vertical plane the curves for the upstream and downstream split foil readings coincide, indicating a perfect alignment of the BSP-V with the beam axis.

Secondly, these beam scans were repeated with a target in the beam. In addition to the split foil signals, the target multiplicity and the halo signal were recorded during these operations.

When the beam hits the target centre, the multiplicity reaches its maximum. The position of the beam for maximum multiplicity is then compared with respect to the position when it is centered onto the upstream split foils. If these two positions coincide the target and the upstream split foils, used for the steering of the proton beam are considered to be perfectly aligned in respect to each other.

Figs. 4 and 5 show the results obtained for the target T24/1, where the multiplicity and the split foil signals are plotted as a function of the horizontal respectively vertical beam positions. The beam widths (FWHM) measured with a standard miniscanner (BBS) upstream of the target station T24 were 1.7 mm in horizontal and 1.5 mm in vertical direction. The target diameter is indicated in the upper graph.

The lower plot shows the normalized signals of the halo detector and of the split foils of both the upstream (TBIU) and downstream (TBID) detector. Between the centre of the multiplicity distribution and the zero-crossing of the split-foil signals a good agreement was found. However, the split foil curve as recorded with the TBID monitor, shows a zero-crossing which is less steep than the curve from the TBIU. This is explained by the well known fact that the beam downstream of the target, i.e. secondary particles plus non-absorbed protons has a larger distribution than the incident proton beam. Nevertheless, even when the beam is intercepted by a target of about one interaction length, the split foils of the downstream monitor give a reasonable indication of the beam position.

Simultaneously with the target multiplicity, the combined neutron + γ flux was recorded as measured with a counter (EXPT(3)) of the NA6 experiment (see dashed curves in figs. 4 and 5). This measurement shows that the maximum of the target multiplicity coincides with a maximum neutron + γ flux. Consequently, a beam steered on the split foil centre of the TBIU monitor will also hit the target centre which in turn corresponds to maximum of secondary particle flux.

For comparison the measurements, made during a vertical scan with the proton beam on the aluminium target T24/2 of Ø 1.5 mm diameter, are shown in Fig. 6. The results are similar to the ones obtained for T24/1 proving a perfect alignment of the upstream (TBIU) plus downstream (TBID) monitor and the aluminium target with the axis of the incident proton beam.

4. Conclusion

The measurements reported here show that a long "pencil-like" target with a minimum of "undesired" support material is operating successfully in the Experimental Target Station T24. Although the target container and the upstream (TBIU) and downstream (TBID) monitor are independent units, rapidly exchangeable in case of failure, their overall alignment is accurate to within $\sim$ 0.1 mm as measured with the proton beam.

The indexing mechanism used for the selection of each of the two targets guarantees for both a reproducibility in positioning of $\leq$ 0.02 mm which is far more accurate than can be verified by the described beam scan method.

Because of the accurate alignment of the target monitors with the target, a proton beam steered on the split foil centre of the TBIU monitor will also hit the target centre. For this beam setting the target multiplicity reaches its maximum, which in turn coincides with a maximum flux of high energy neutrons. Consequently, an optimum targetting can be surveyed by a continuous observation of the target multiplicity. In case the multiplicity drops for a given target, either the beam is badly steered which will be revealed by the split foil reading or the waist of the primary beam is blown-up. The latter effect can be globally observed via the halo detector or more detailed by a beam profile measurement.

Reported by: W. Kalbreier

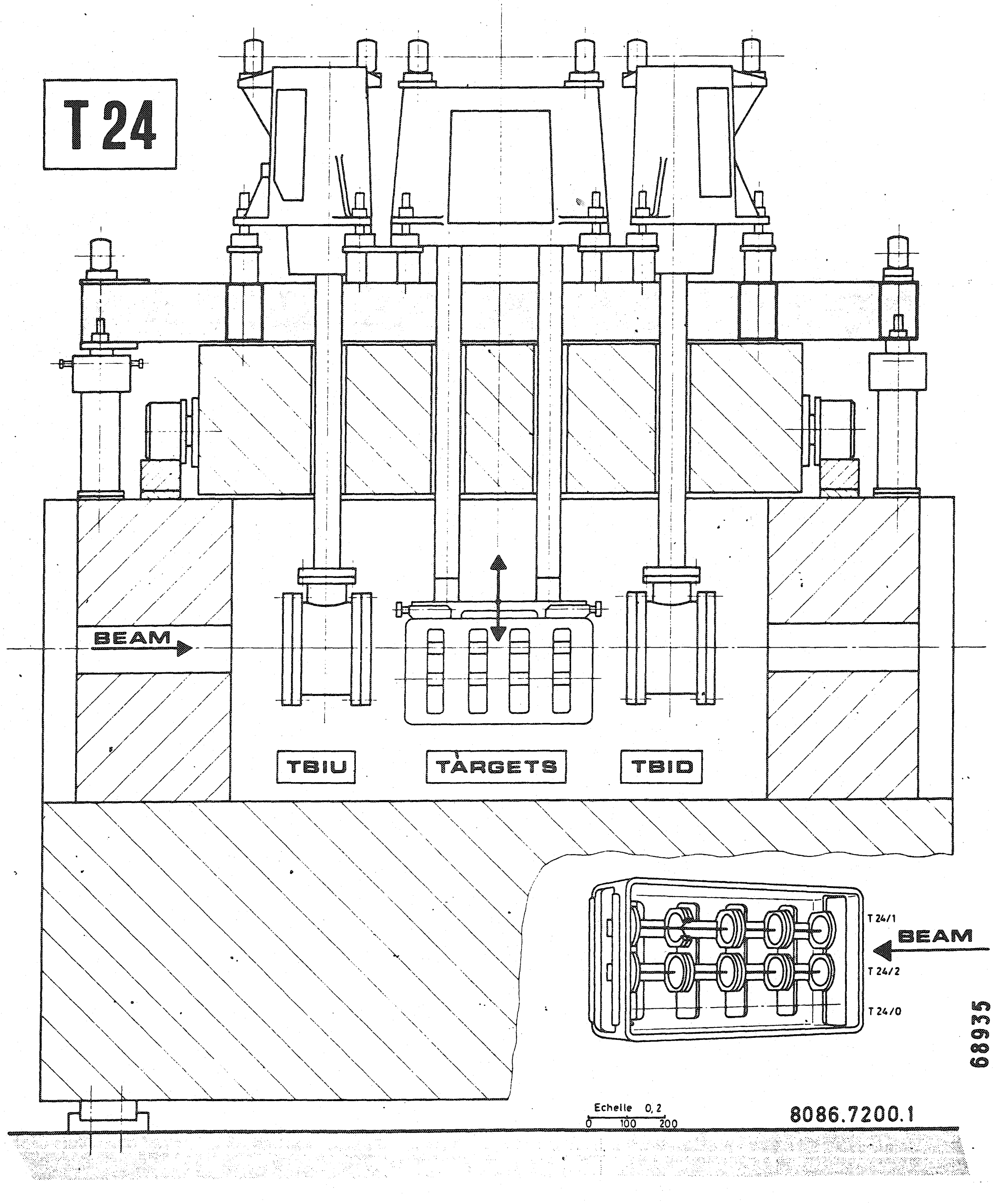


Fig. 1a - The vertical cross-section of the Experimental Target Station T24. The target container and the upstream (TBIU) and downstream (TBID) monitors are suspended from a common frame above the mobile top shielding.

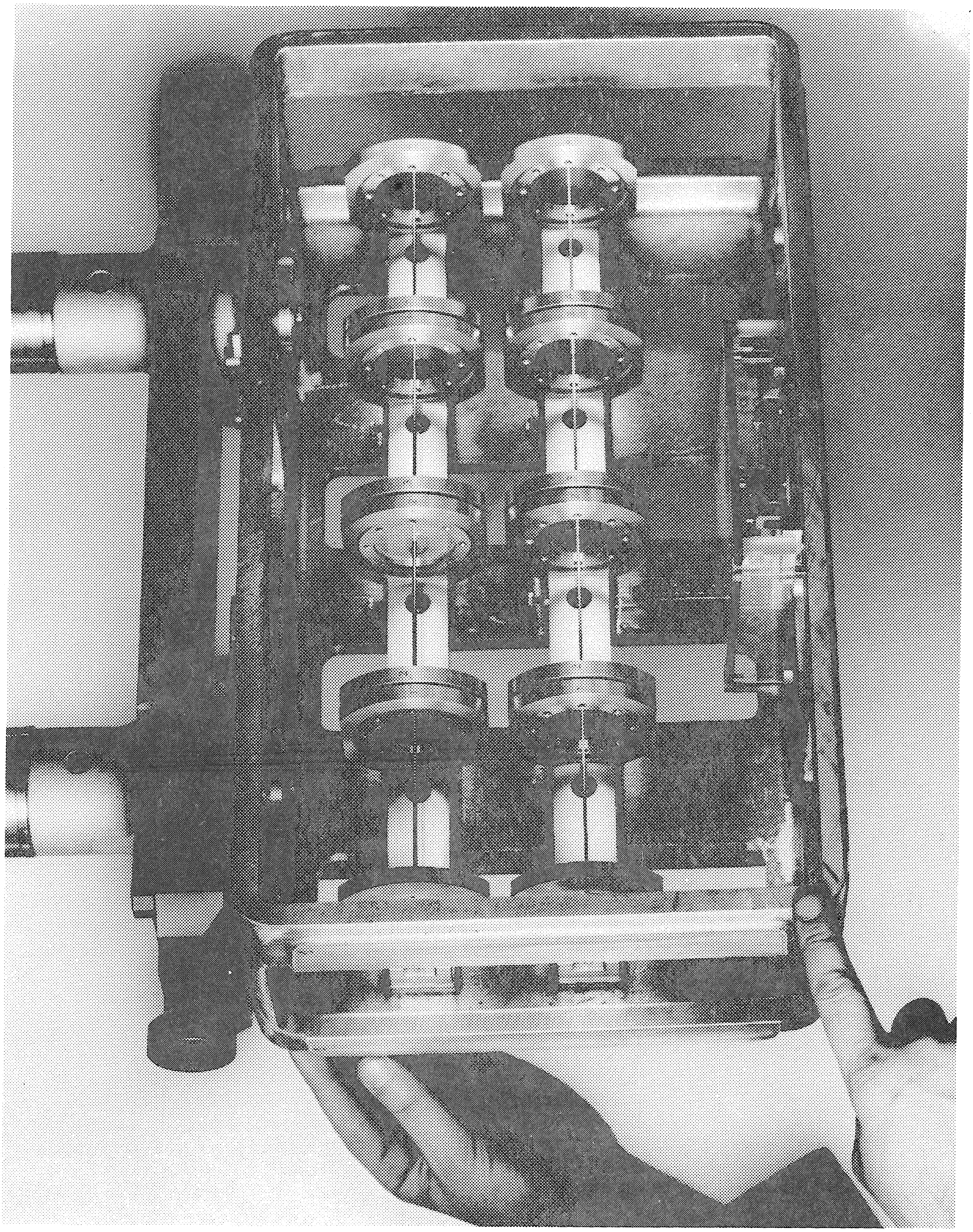
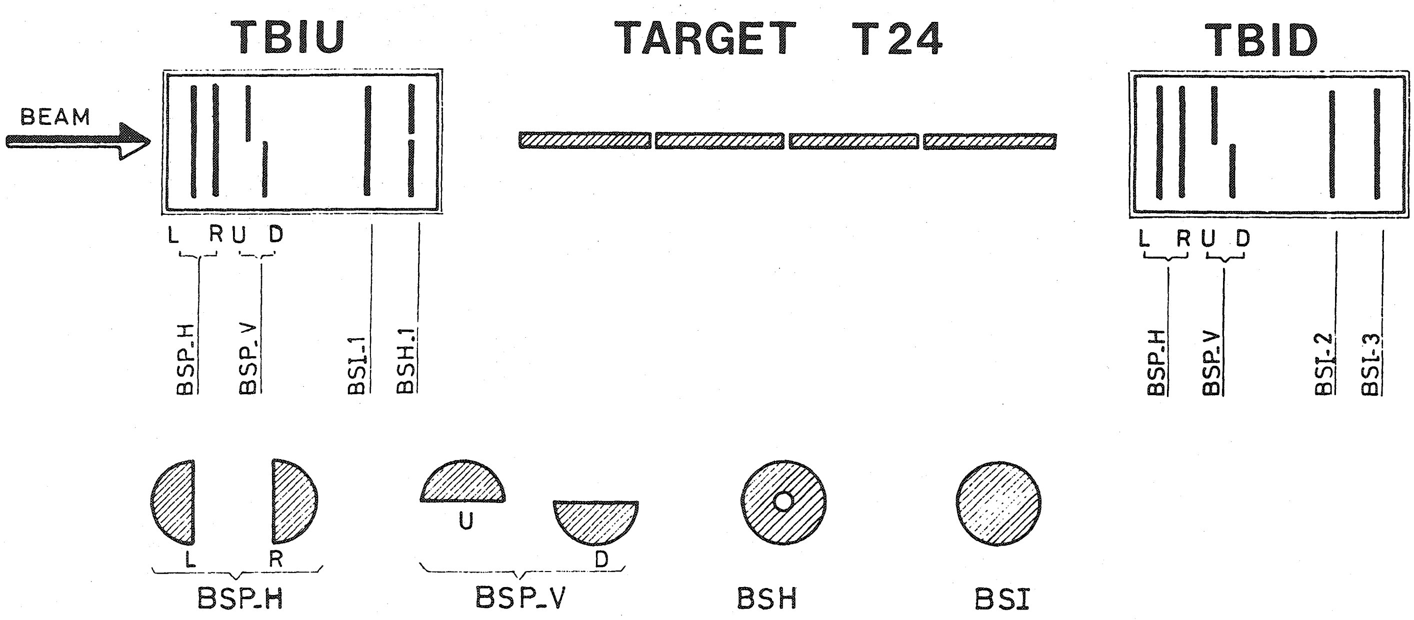


Fig. 1b - The photo shows the detailed layout of the target container. The levels inside the container were demounted after the accurate horizontal positioning of the targets.



Detector	Measures
BSP-H	HORIZONTAL BEAM POSITION
BSP-V	VERTICAL BEAM POSITION
BSH	BEAM HALO
BSI	BEAM INTENSITY

HALO FOIL	HOLE DIMENSION
BSH.1	ϕ 2 mm

Fig.2

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Fig. 2 - Experimental Target Station T24

Schematic layout (side view) of the target set-up and its associated upstream (TBIU) and downstream (TBID) beam detectors.

T 24/0 HOR. + VERT. SCAN

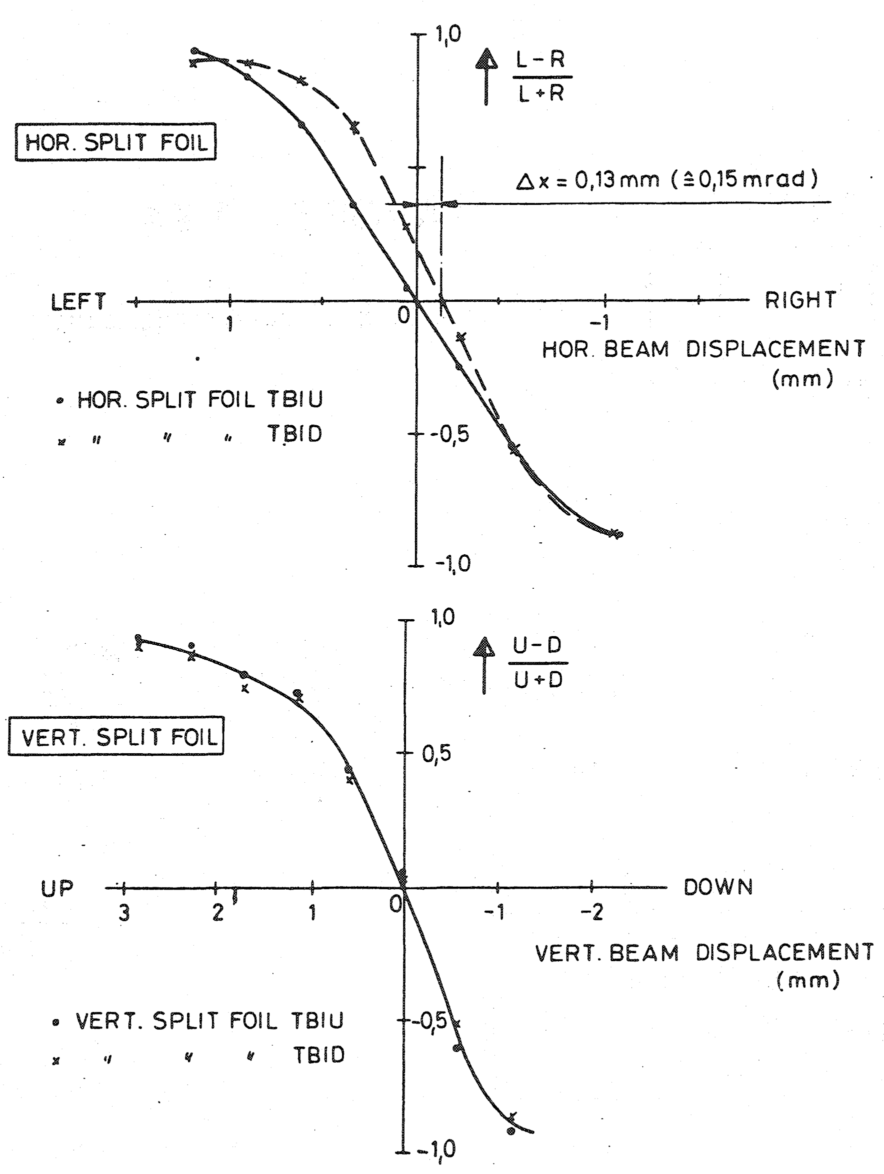

Fig. 3

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Fig. 3 - T24/0 Horizontal and vertical scan

Split foil signals of the upstream (TBIU) and downstream (TBID) beam monitors as a function of the horizontal respectively vertical displacement of the proton beam. The target was out of beam.

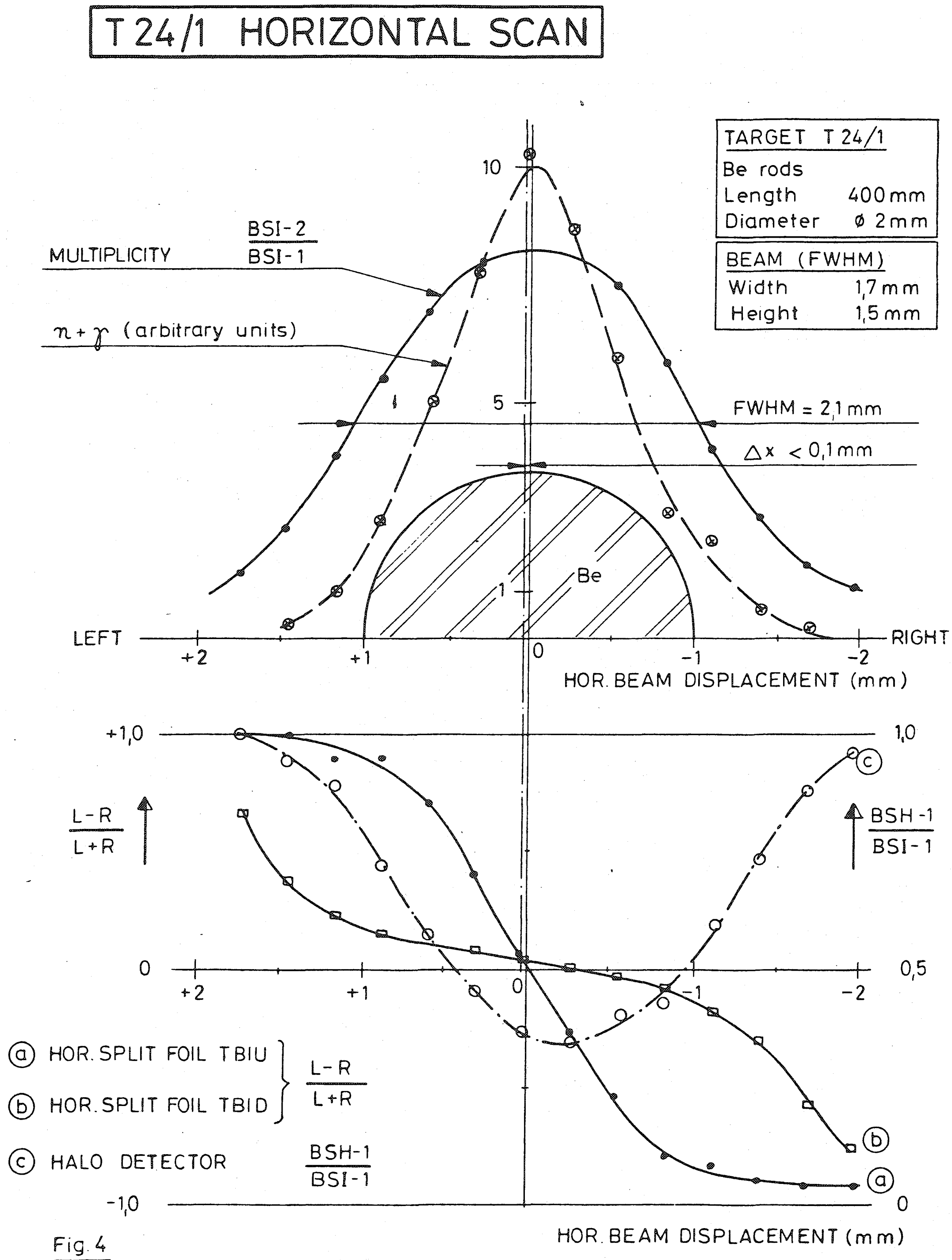

Fig. 4

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Fig 4 - T24/1 Horizontal scan

Beam detector signals of TBIU and TBID as a function of the horizontal beam displacement across the target. The upper diagram shows the target multiplicity and the neutron + γ flux. The lower diagram gives the normalized signals of the split-foils and of the halo detector.

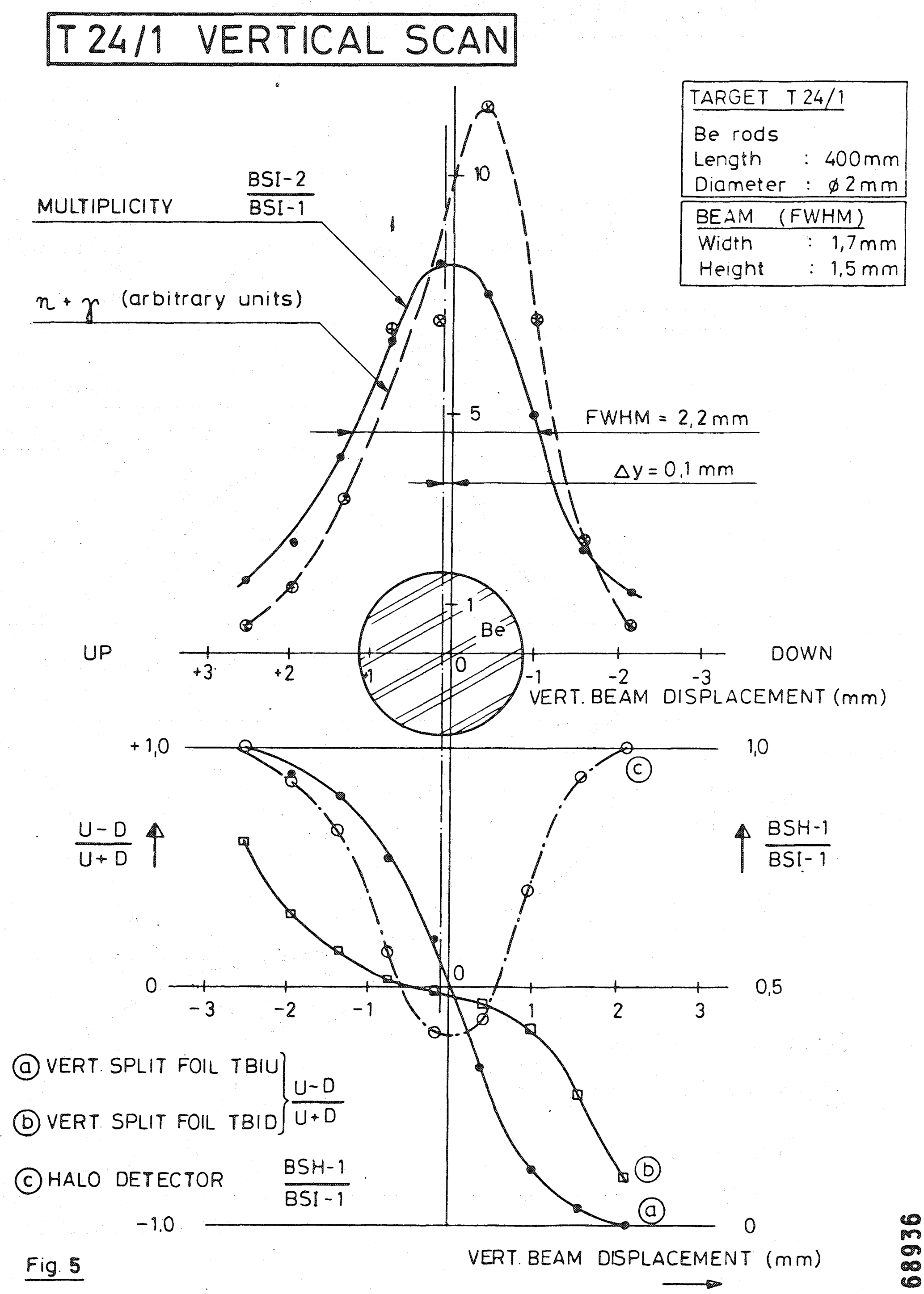

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Fig. 5 - T24/1 Vertical scan

Beam detector signals of TBIU and TBID as a function of the vertical beam displacement across the target. The upper diagram shows the target multiplicity and the neutron + γ flux. The lower diagram gives the normalized signals of the split-foils and of the halo detector.

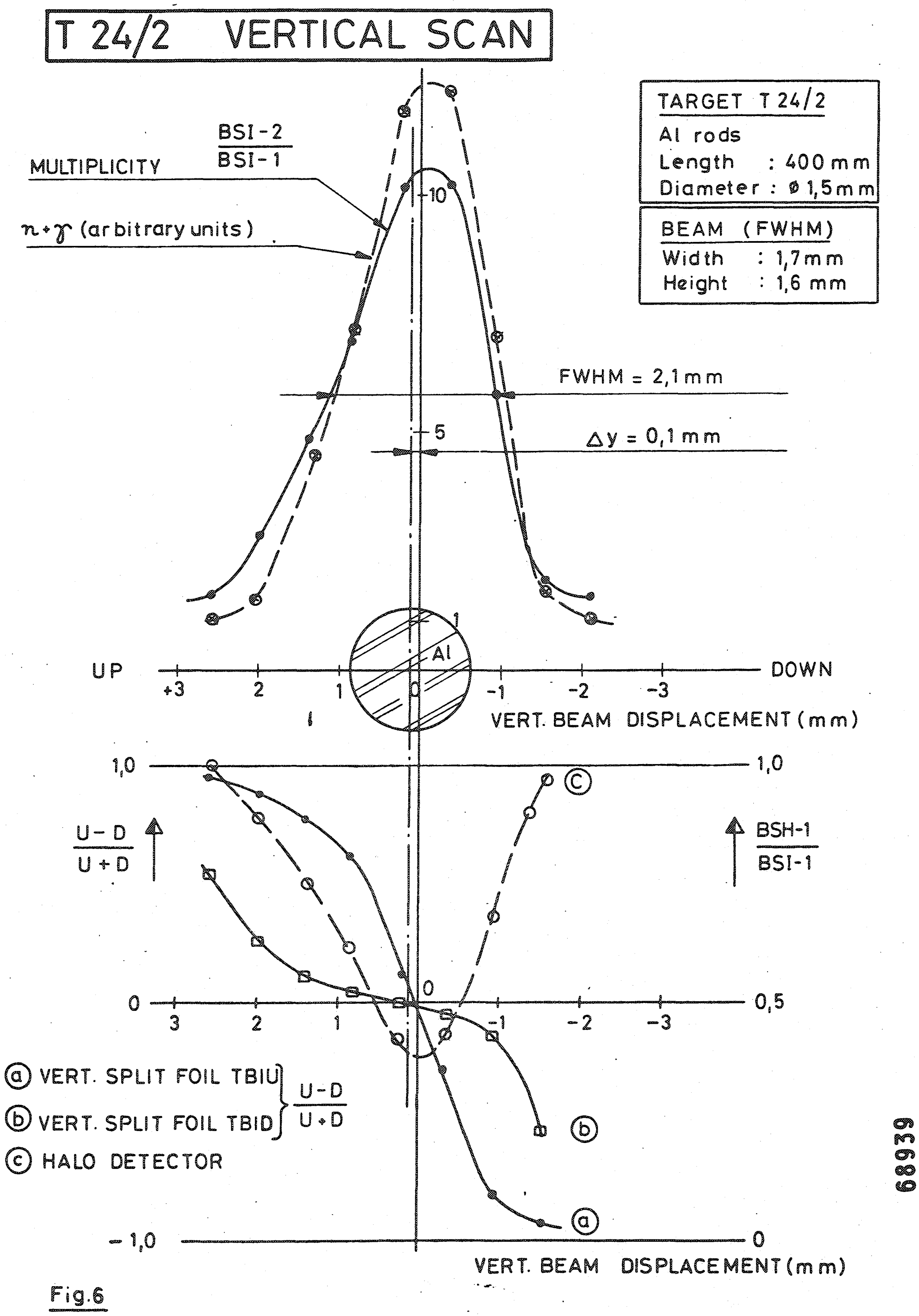

Fig. 6 - T24/2 Vertical scan

Beam detector signals of TBIU and TBID as a function of the vertical beam displacement across the target. The upper diagram shows the target multiplicity and the neutron + γ flux. The lower diagram gives the normalized signals of the split-foils and of the halo detector.