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# P.S. Internal targets as a nuclear physics tool (1961)

## Introduction

The object of this report is to summarise the target situation in the P.S. and give information which may be of value to the physicists while planning their experiments.

There are three target systems:

1. The 'slow-flip' target.
2. The 'fast-flip' target, (ref. 1)
3. The 'six-head' target, (ref. 2) which is an improvement of the standard 'slow flip'; with this mechanism six target heads can be interchanged between machine cycles according to a preselection; all six target heads have the same azimuthal and radial position.

Fig. 1 shows three pictures of the 'slow-flip' and 'fast-flip' target. These target mechanisms are used for the production of secondary particles. The burst-lengths are between 300 µsec and 150 msec.

The following subjects will be discussed:

Target positions.
Target heads and source dimensions.
Secondary beam production.
Beam dumping; target efficiencies; short burst limits.

## §1 Target positions

The source position is determined by its azimuthal,($\Theta$) radial($r$) and vertical($z$) co-ordinates. $\Delta z = \Delta r = 0$ is the middle of the vacuum chamber.

### Azimuthal position

In principle a target unit with its two or six + one target heads can be installed on the downstream side of each magnet unit. Up to now the straight sections 1, 2, 4, 5,7, 9 and 10 are the normal positions.

A target head, which we shall consider as a point, can be fixed within some mms from a line (with $\Theta$ = 122 mm) downstreams from each magnet unit (see fig. 2). The exact $\Theta$ position of the target is in dependence on the type of target head. The magnetic field at the position of the target is around 4500 Gauss at 24 Gev beam energy.

There are some special straight section vacuum chambers available with azimuthal target positions, where the magnetic field is negligibly low (e.g. in the middle of a straight section).

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Radial position

If $\Delta r = 0$ is the middle of the vacuum chamber, safe figures for radial target positions at standard target operations are:

$$-25 \text{ mm} < \Delta r < +25 \text{ mm}.$$

The reproducibility of the 'slow-flip' target working position ('up' position) from pulse to pulse, taking into account heating of the magnet up to 80 $^{o}$C, is smaller than 0.7 mm. The reproducibility of the radial displacement is $\pm$ 0.1 mm. The reproducibility of the radial position of the beam is about 0.2 mm.

Vertical positions

The vertical position of the target head (e.g. point source) is the local equilibrium orbit belonging to protons of nominal energy; this position is in coincidence with the middle of the secondary beam transport apparatus.

§ 2. Target heads and source dimensions

Different types of target heads have been developed for different kinds of experiments. Normal target heads are point sources, blocks and fingers. The normal target material is beryllium, but other materials such as polythene, carbon, gold, aluminium and beryllium-copper are in use.

A survey of the heads with the standard burst shapes and used materials are given in Fig.3 (for long bursts) and Fig.4 (for short bursts); the burstshapes were detected with monitors placed above the targets (ref.3). The total thickness of the six targets on the 'six-head' unit has to be less than 18 mm.

Using a radio-autographical method, the effective source dimensions of several target heads were determined. Three typical examples of effective source dimensions are given:

a) A L foil

See Fig.5a and Fig.5b.

The 50 µ AL foil was irradiated in a defocusing straight section 4 under normal long burst operational conditions (see § 3. table 2).

The Fig.5a shows that 90% of the total radio-activity of the foil is found in a region of 1.1 cm$^2$ with a vertical height of 24 mm and a radial extension of 6 mm.

The irradiation of the support can be reduced to a negligible level by using a beam-kicker-technique (see § 4.).

Note 1:

In focusing straight sections 1,3,5 etc. the effective source of this foil should be smaller in the vertical direction.

Note 2:

The source dimensions should also be smaller for lower Z target materials e.g. Be foils (smaller scattering effect).

b) Be point source.

See Fig.6.

This Be target was irradiated in straight section 1 under normal operational conditions. No intensity distribution was found in the ∅ 4 mm disc. This is in agreement with the rather soon building-up of betatron oscillations due to energy loss and coulomb scattering.

93% of the total radio-activity of this target was found within the "shadow" of the disc (see fig.6).

c) Finger target

The effective source diameter is estimated to be in the order of 1.5 - 2 times larger than the actual proton beam diameter. The undisturbed radial beam intensity distribution is shown in Fig.7. So the beam diameter, including 90% of the total beam intensity, is 4.5 mm in focussing machine straight sections 1,3,5....

The beam intensity distribution in defocusing sectors 2,4,6... have been measured by Richter.** Differences in beam diameter in radial and vertical direction, in focusing and defocusing sectors seem to be less than 1 mm, which is the accuracy of the method.

## § 3. Secondary beam production

There are two types of bursts (secondary beams) available from the above mentioned target heads:

a) short burstlengths between 300 μ sec. and 2 m sec.
b) long burstlengths between 2 m sec. and 150 m sec.

Several machine techniques have been tried out for the production of these bursts. Table 1 and table 2 give a survey of those machine operations, which seem to be reliable and also practical in use.

TABLE 1: Short burst production (bunched beam)

| Machine Operation | Target head (see §2) | Target speed | Beam speed towards target | Burstlength 90 % | Beam consuming |
|---|---|---|---|---|---|
| Target traversing the beam | finger | 12 - 35 mm/msec | 0 | 300-800 μ sec | 1 - 35 % |
| R.F.Beam steering on the target | thick point source / block (Be) | 0 | 5 mm/msec. | 1.2 m sec | 100 % |
| De-acceleration during rise of magnetic field | thick point source | 0 | 7.5mm/msec* | 1 m sec | 100 % |
| | block (Be) | 0 | 7.5mm/msec* | 600 μ sec | 100 & |

* Theoretical value for 120 kV energy loss per turn during rise of the magnetic field.

** Not published.

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TABLE 2: Long burst production (debunched beam)

| Machine Operation | Target head (see § 2) | Target speed | Beam speed towards target | Burstlength | Beam consuming |
|---|---|---|---|---|---|
| Broadened beam spiralling on the target during the flat top of the magnetic field. | thin point source<br>line source<br>foil | 0 | 0.15 - 0.25 mm/msec | ~120 msec. | 100% |
| | block ($C,CH_2$) | | | 10-30 msec. | |

Several kinds of beam sharing between different or identical targets are possible. Some examples, which can be considered as standard procedures, are mentioned below:

a) Sharing between machine cycles with short and/or long burst targets; only one target is in operation during each machine pulse.

b) sharing of the beam between a short ('finger') and a long burst target during the same machine cycle;

c) sharing of the beam in variable ratios between two long burst or short burst targets in different straight sections of the machine; with this kind of sharing the machine operation is extended by introducing betatron oscillations to the closed orbit.

## § 4. Beam dumping; target efficiencies; short burst limits.

Some secondary features concerning targets in operation with the machine are mentioned in this paragraph.

### Beam dumping.

For certain experiments it is necessary to lower the background of secondary particles originating from the target frame (e.g. foil target) or from the vacuum wall in the target area. Dumping of these particles to a negligible amount can be performed by using kicker magnets in such a way, that most of the scattered protons hit the chamber far away from the target region. This procedure has already been described by W. Richter (ref.4)

### Target efficiencies.

The target efficiency ($\eta$) is defined as:

$$\eta = \frac{\text{number of protons absorbed and scattered out of the machine at target position}}{\text{number of accelerated protons}}$$

Relative efficiency values can be measured by comparison of the integrated counter burst from the internal target divided by the primary proton intensity (see ref.5)

Only a few results could be obtained. For the light target materials such as Be, C and $(CH_2)_n$ maximum differences in efficiency were found to be 6%, which is the accuracy of the method ($\pm$ 3%).

If the absolute measurement of efficiency using a large AL foil target (ref.6) is correct (~50%) then it seems from preliminary results that absolute efficiencies from the above mentioned light materials are around the same value.

## Short burst limits

The burstlengths from the existing 'thick' point source targets with full primary beam consumption can not be made much shorter than 1 msec by improving machine techniques. The limiting factor is especially the mass of the point source. For 1 msec burstlength the minimum diameter of the target is 3 mm. Increasing of the mass shortens the burstlength. This is shown already in §3, Table 1, with the machine operation: 'deacceleration during rise of the magnetic field' on the thick point source target and the block target.

## Acknowledgements

I thank G.L. Munday and W. Richter for the worthwhile discussions and suggestions on the numerous target problems and Ch. Brooks, M.v.Rooy and J. Combe for their excellent assistance during this period of operational and short term target development.

Th. Sluyters 15.11.1961

Ref. 1. W. Richter and Th. Sluyters: 'A fast target' MPS/Int/Va/60-24.

Ref. 2. Ch. Brooks and W. Richter: 'A six-head target' MPS/Int/Va/61-5.

Ref. 3. M.v.Rooy and Th. Sluyters: 'The target monitor system of the CPS' MPS/Int/Va/61-10.

Ref. 4. W. Richter: 'Production of secondary beams at CPS' Contributed paper to Brookhaven Conf. '61. MPS/Int/Va/61-8.

Ref. 5. Th. Sluyters: 'Some experiences concerning internal PS Target efficiency measurements' MPS/Int/Va/61-9.

Ref. 6. J. Geibel: 'Results of measurements with the fast large foil target' MPS/Int/AL/61-8.

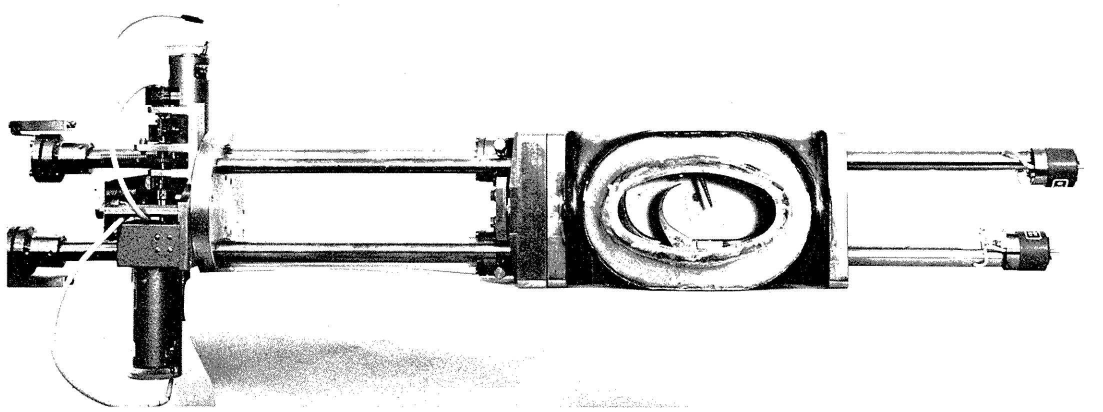


Fig. 1a General view of the target unit, mounted in a pump manifold; each unit has two independent flip targets; target heads are seen through the clearance of the vacuum chamber; actuating magnets on the right; motordrive for changing the radial position and potentiometer for position indication on the left side.

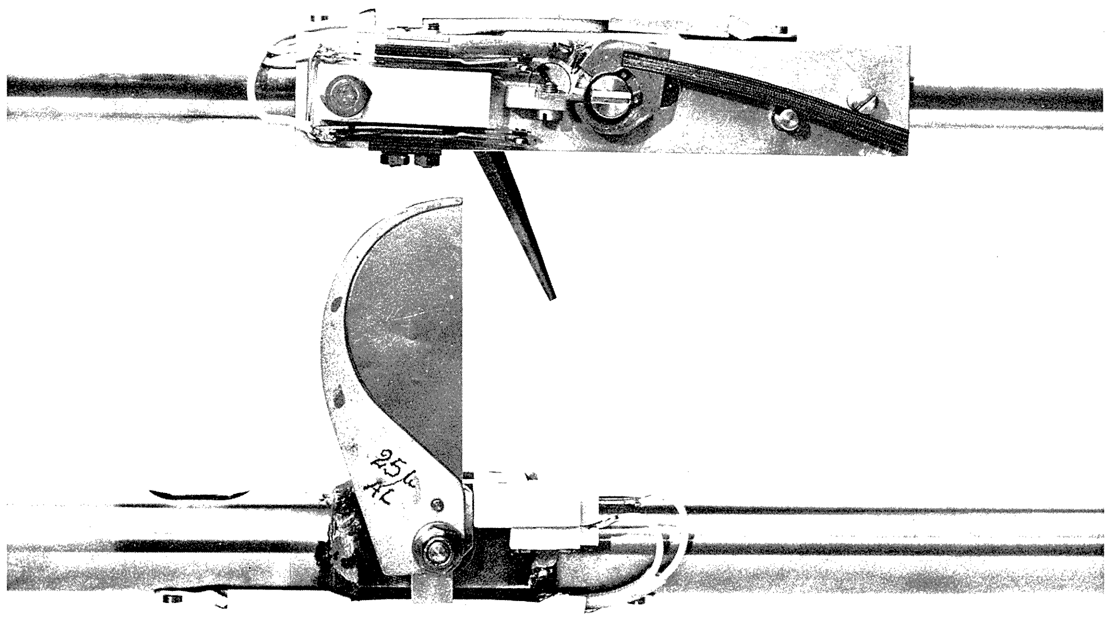


Fig. 1b The actual target enlarged; "slow-flip" (foil) target on the bottom rod; "fast-flip" (finger) on the top rod; small contacts indicate target "up" position.

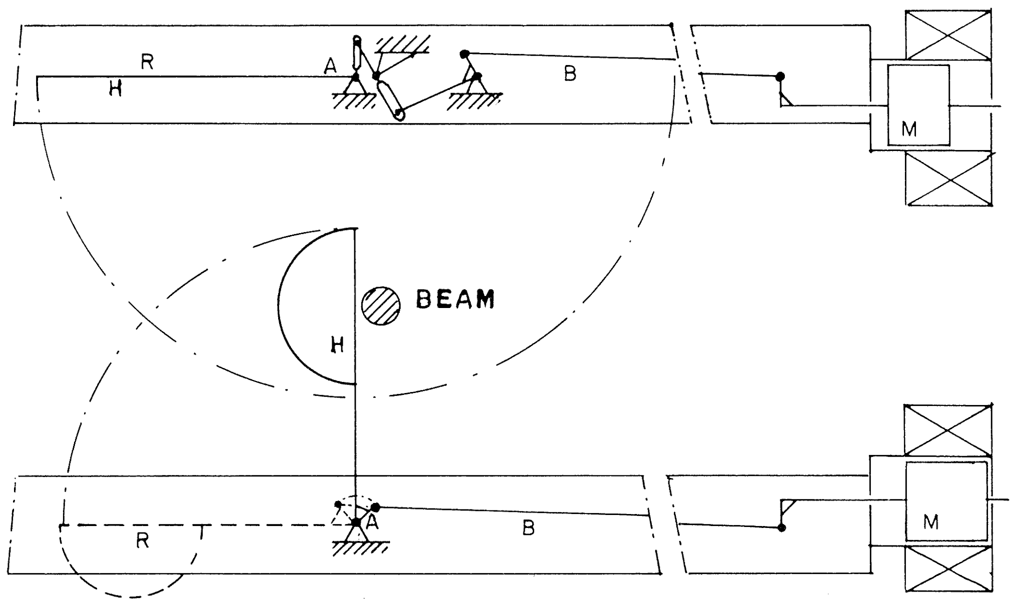



Fig. 1c Schematic design of the moving mechanism; small magnet on the right (M) pulls at the target head (H) fixed on axis (A) into working position via a band (B); the "slow-flip" target turns ~90°, the "fast-flip" about 180°; springs are used to decelerate and return the head into its rest position (R).

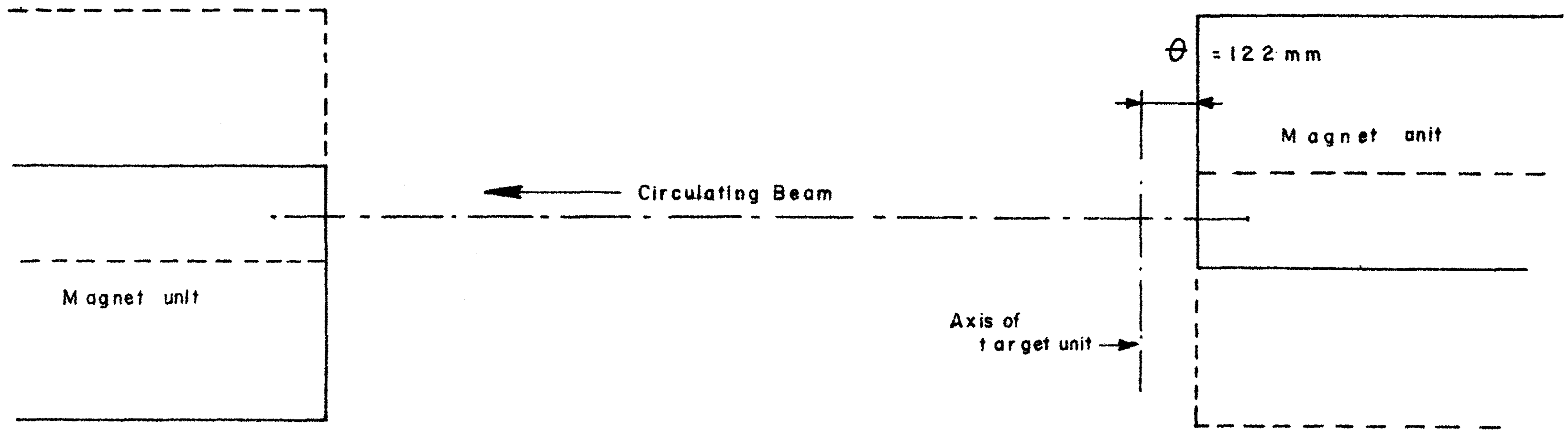



Fig. 2· Azimuthal target position. (see text page 2)

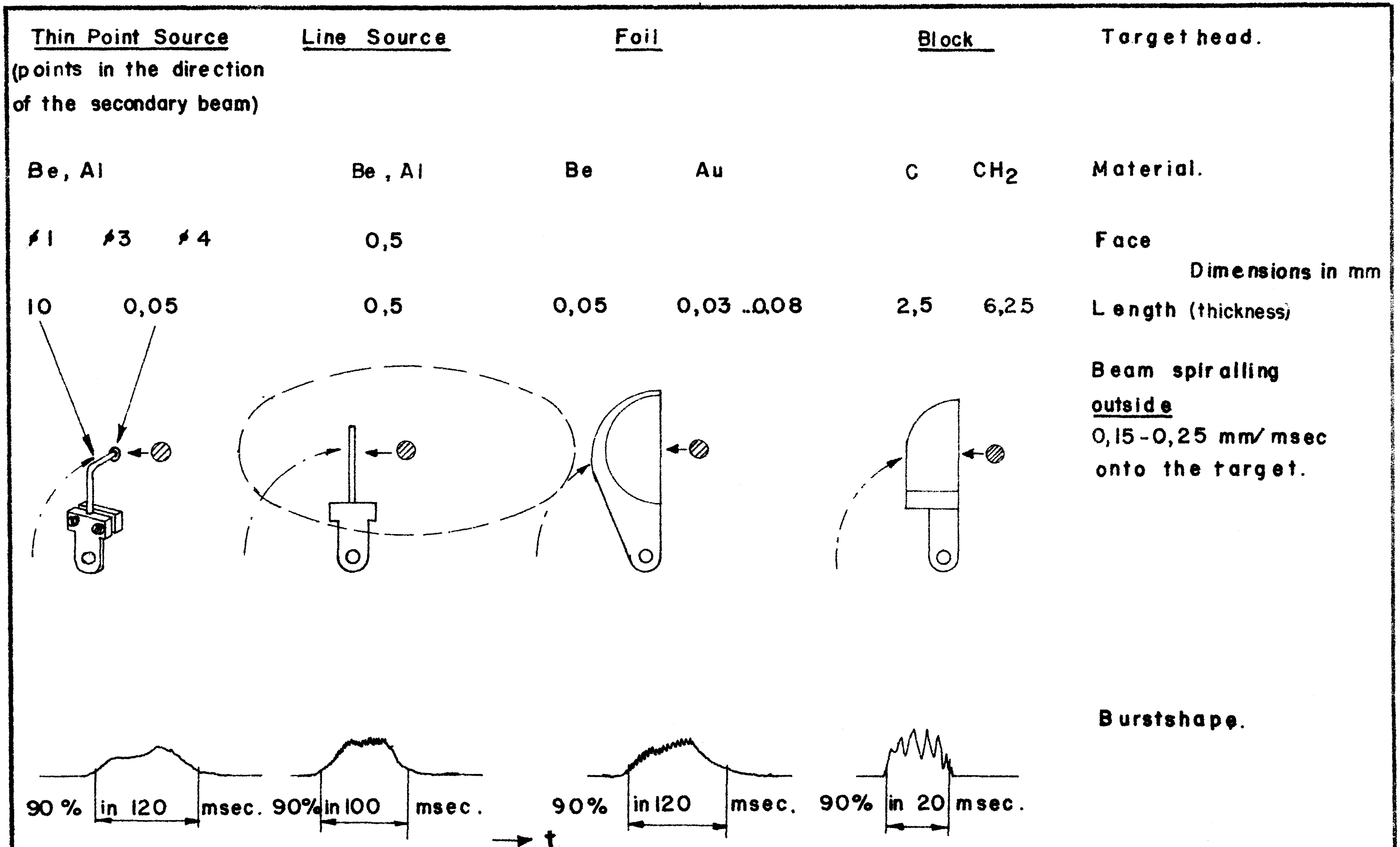
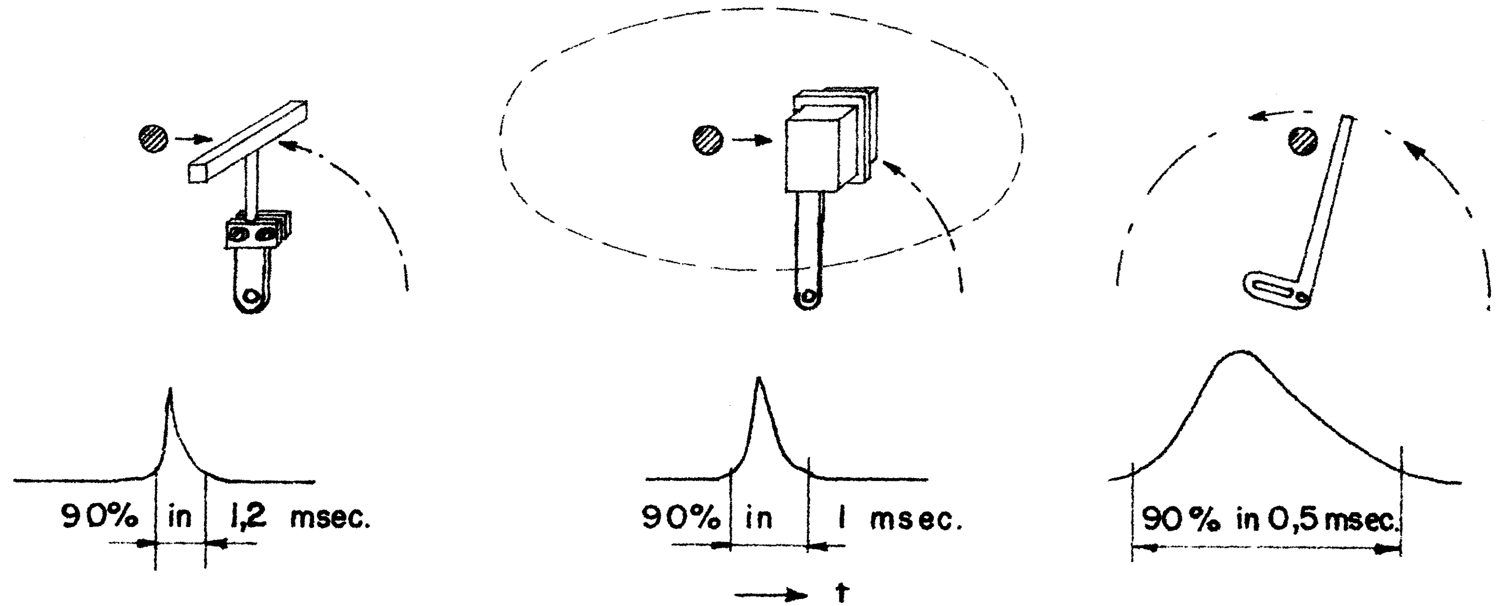



**Fig.3** Long-burst-targets and their burstshapes

| Thick Point Source (points in the direction of the external beam) | Block | Finger | | Target head |
| --- | --- | --- | --- | --- |
| Be, Al. | Be. | CuBe. | Al. | Material |
| 3x3. 3x4. 4x4. | 15 x 20 | 0,1 ... 3. | | Face. |
| 40 | 15 | 0,1 | 0,5 | Length. (thickness) |

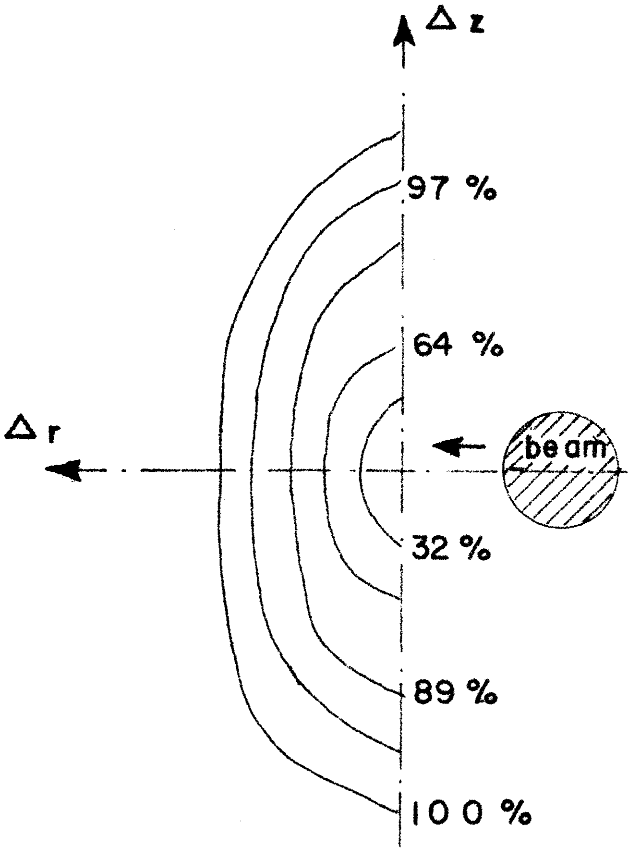
Dimensions in mm.

Beam steered <u>inside</u>
5 - 7,5 mm / msec.
onto the target.
Finger speed
12 - 35 m/sec.




Burstshape.

**Fig.4.** Short-burst-targets and their burstshapes.




scale 2,5 : 1

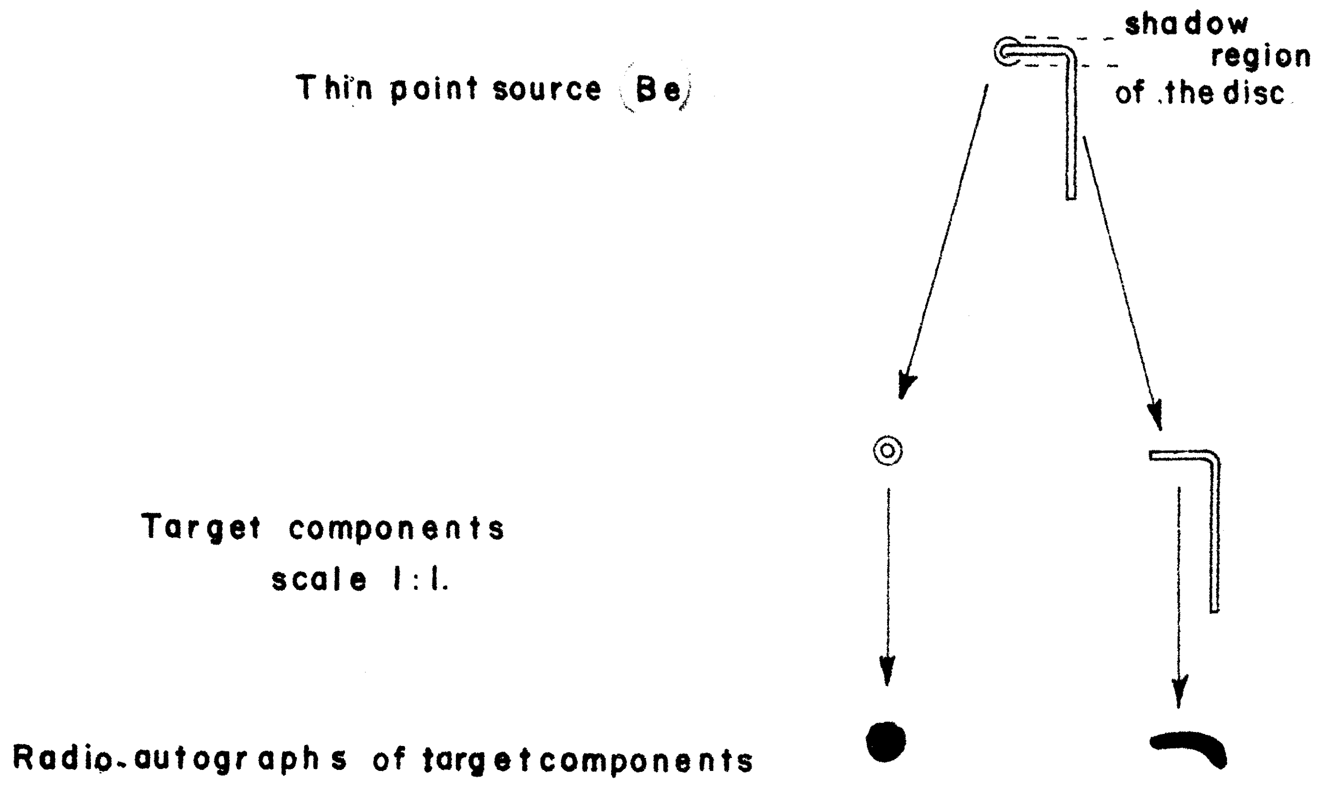
Fig : 5 a

scale 1 : 1

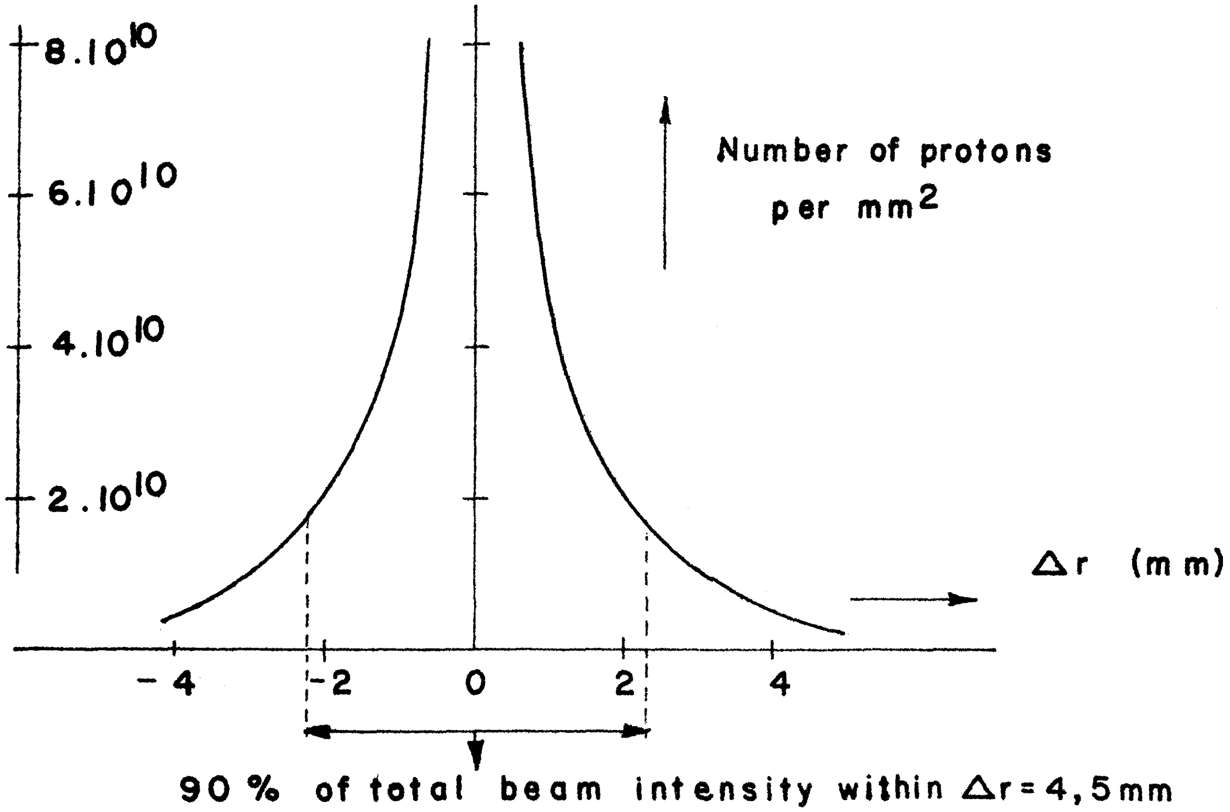
Fig: 5 b

Fig: 5 a Equi-intensity lines from a 0,05 mm Al. foil. 90 % of the radio-activity of the foil is found within a surface area of 114 $mm^2$

Fig: 5 b Radio-autograph of the same Al. foil in its Al support, which is activated by scattered particles.




<u>Fig.6.</u> Radio-autographs of a thin Be point-source.




<u>Fig: 7.</u> Radial beam intensity distribution at 24 Gev in the focussing sectors 1, 3, 5, etc. The total beam intensity is $3.10^{11}$ protons.