Production of positron emitters at the SIN cyclotron facilities

R. Weinreich

Eidgenossisches Institut fur Reaktorforschung (EIR),
Wurenlingen, Switzerland
and
Schweizerisches Institut fur Nuklearforschung (SIN),
Villigen, Switzerland

In the past, the needs of the Swiss cyclotron isotope program were only met by the Injector I cyclotron at SIN, Villigen. The limited beam time there, however, did not allow for the establishment of a regular PET program including clinical applications. Only less than 1 Ci ^{18}F could be produced once per week, by proton irradiation of enriched $H_2{}^{18}O$ behind a degrader <1-3>.

With the start of the new Injector II cyclotron <4> in 1985, which is expected to produce 2 mA of 72 MeV protons, the situation has changed. As shown in Fig. 1, a beam current of 100 μA will be continuously stripped off from the main beam (the principle is described in Ref <5>) and directed into a special area. In 1984/86 the target station "West" will be realized, "Ost" will follow in 1987, and "Nord" later. Then, the beam will be available around the clock in a semi-parasitic way, and the isotope production program will cover also the need for short-lived positron emitters with the background of a routine clinical use.

The target station "West" consists of two parts (Fig. 2): in a movable part, solid state or capsule targets are irradiated by 72 MeV protons, after EOB they are transported into the hot cell by a monorail system. A stationary target system is installed directly behind the movable one, it is entered by the degraded beam (45 MeV). The stationary system is for the production of positron emitters.

The high-current production of longer-lived radioisitopes simultaneously with positron emitters in one and the same target station causes problems:

- The incident energy of the protons is straggled as shown in Fig.3 for the degrader material copper<6>. If such a homogeneous degrader is replaced by a production target, this effect is enhanced by density variations, hot spots, etc. Thus, the entrance energy in the positron target has a broad distribution, consequently the target generally has to be constructed with larger dimensions than in low-energy medical cyclotrons.
- Figure 4 illustrates the activation of copper by protons of different energies <7> as well as the neutron production rates <8>. Under our strong isotope production conditions (100 μA), the target station and vault are activated considerably.

Maintenance and repairs would be possible only after a long cooling time which is inconsistent with maintaining the production program. Thus, we had to consider closed arrangements only.

- Plastic materials have only a limited lifetime in a radiation field. As depicted in Fig. 5 <9>, the expected annual gamma dose would destroy all hoses, cable insulations, thermosettings, resins, etc. We had to consider a system whose movable parts took account of these facts.

Figure 6 shows an arrangement of gas and liquid targets which seems to be a useful compromise between the production needs for positron emitters and the limitations given above. It consists of 7 production targets and 1 beam monitoring target allowing the production of $^{18}F^-$, $^{18}F_2$, ^{13}N, $^{15}O_2$, $H_2{}^{15}O$, $^{11}CO_2$ and $^{11}CH_4$, respectively. All connections are made inflexible, from metals only. All movable parts and joints are placed outside the local shielding. Since the system contains a separate beam monitoring position, the electrical connections are kept to a minimum. The electrical lines are insulated by ceramic material. This target system is now under construction, incuding a remote control system.

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References

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Figure Captions

Fig. 1. Schematic ground-plan of the new isotope production area II at SIN. The beam is permanently stripped off from the Injector II beam. The realization is carried out consecutively: "West" 1985/86, "Ost" 1987, "Nord" 1989. The area is outlined for a maximum beam current of 100 μA (72 MeV).

Fig. 2. Side-view of the target station "West" (schematically). It consists of a movable (^{123}I, etc.) and a stationary part. The system is surrounded by a local shielding and is considered as a closed radiation source, from the point of view of the constructor.

Fig. 3. Angular and energy straggling of 72 MeV protons in copper <6>. The angular straggling is nearly linear with the degrader thickness, the energy straggling becomes effective only at low energies, but then very strongly.

Fig. 4. Activation of copper by protons of different energies (left) <7>. Neutron production rate in a copper target (right) <8>. For other target materials, adequate relations can be assumed.

Fig. 5. Radiation effects in plastics versus the gamma dose <9>. For a Baby cyclotron, 200 Gy per annum are assumed, for a Compact cyclotron 10^4 Gy, and for the Injector II isotope production line, 2×10^6 Gy, respectively.

Fig. 6. Schematic view of the system of gas and liquid targets (from above). The movable part (left) contains in the first phase a metal degrader, in a second phase the degrader will be replaced by a solid state target.

BEAM LINING "ISOTOPE PRODUCTION II" AT SIN

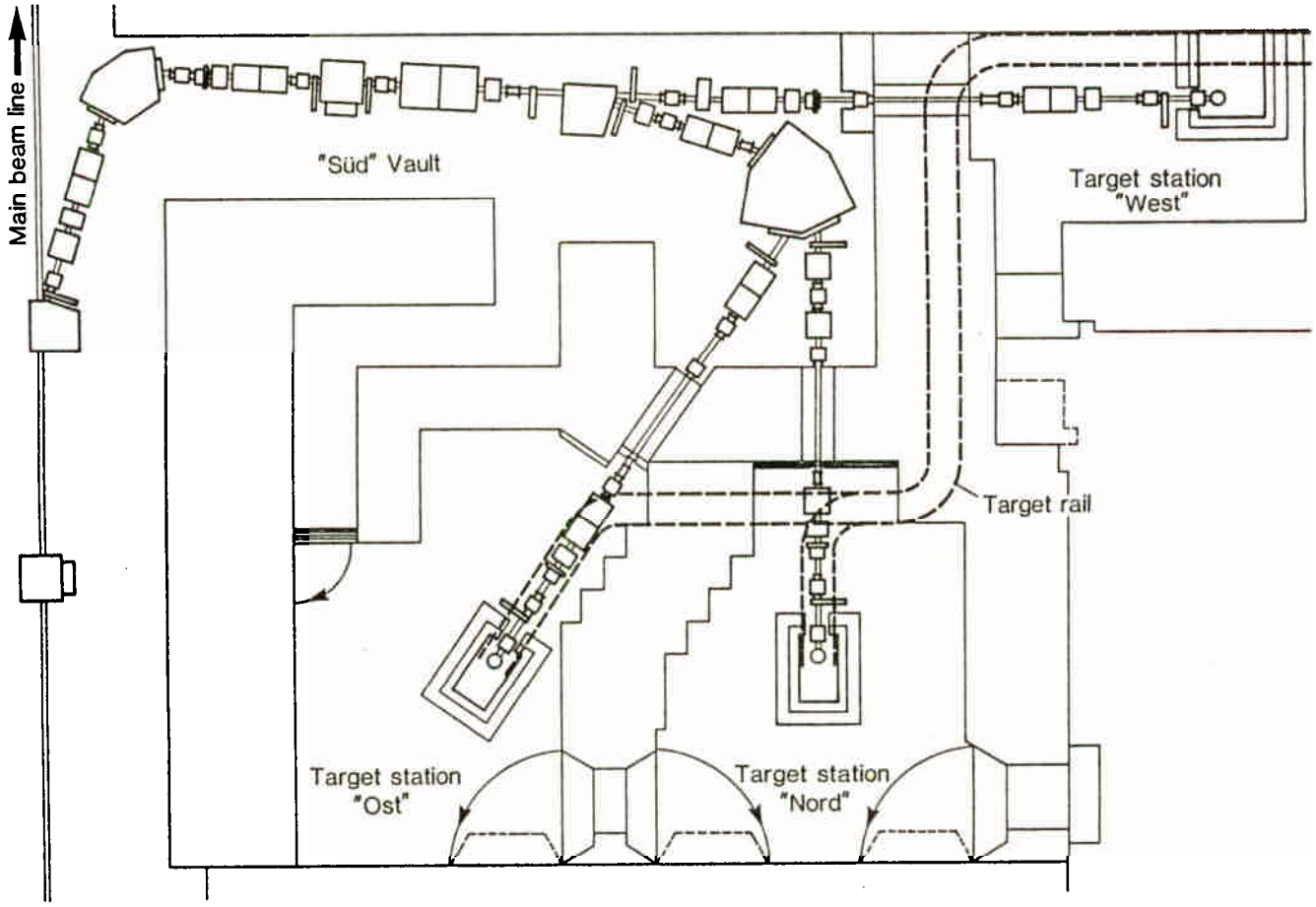


Figure 1

TARGET SYSTEM
(STATION WEST)

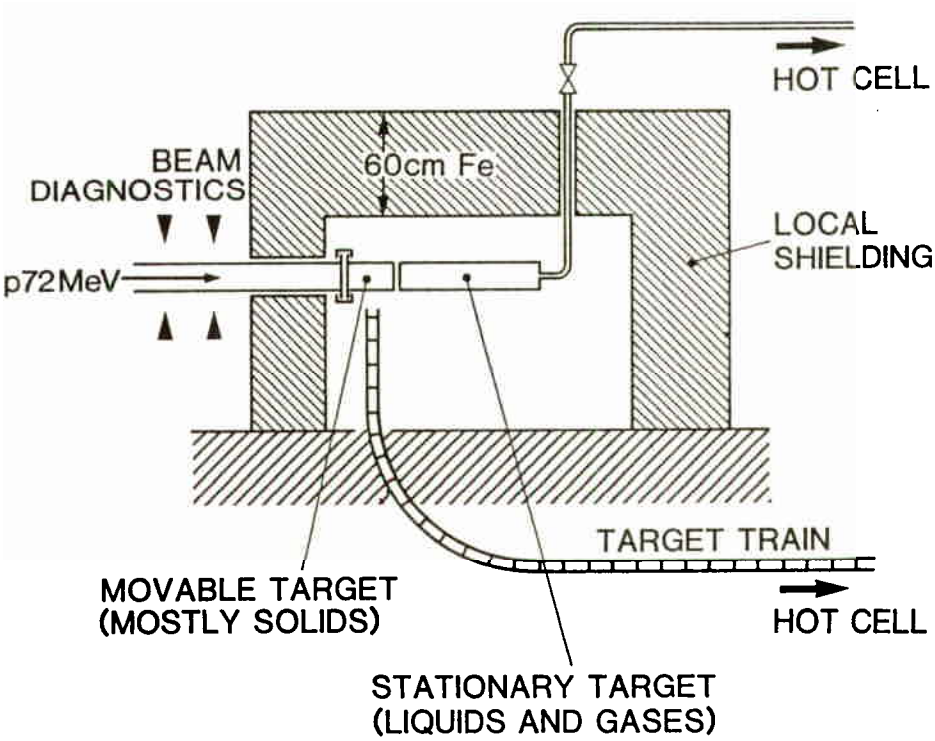


Figure 2

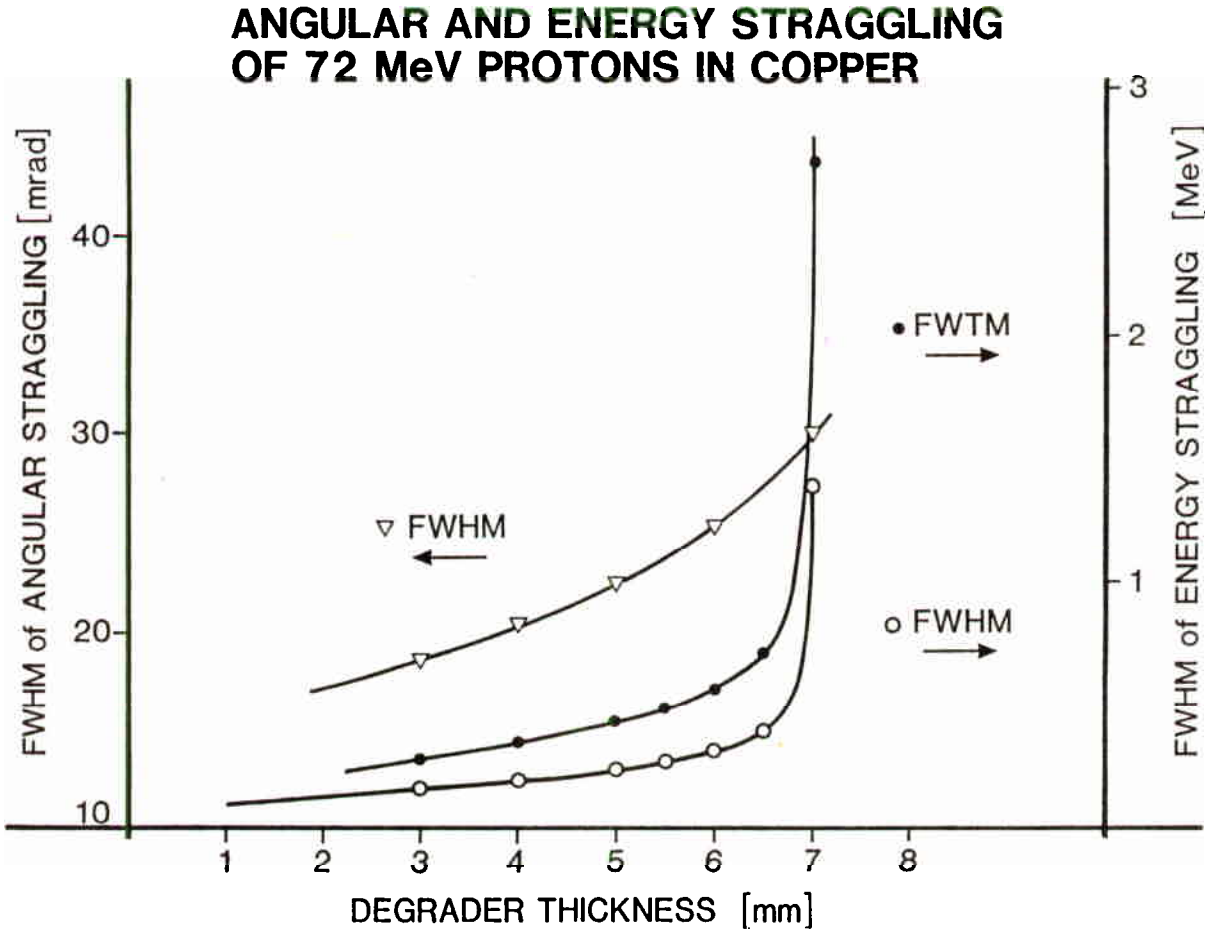


Figure 3

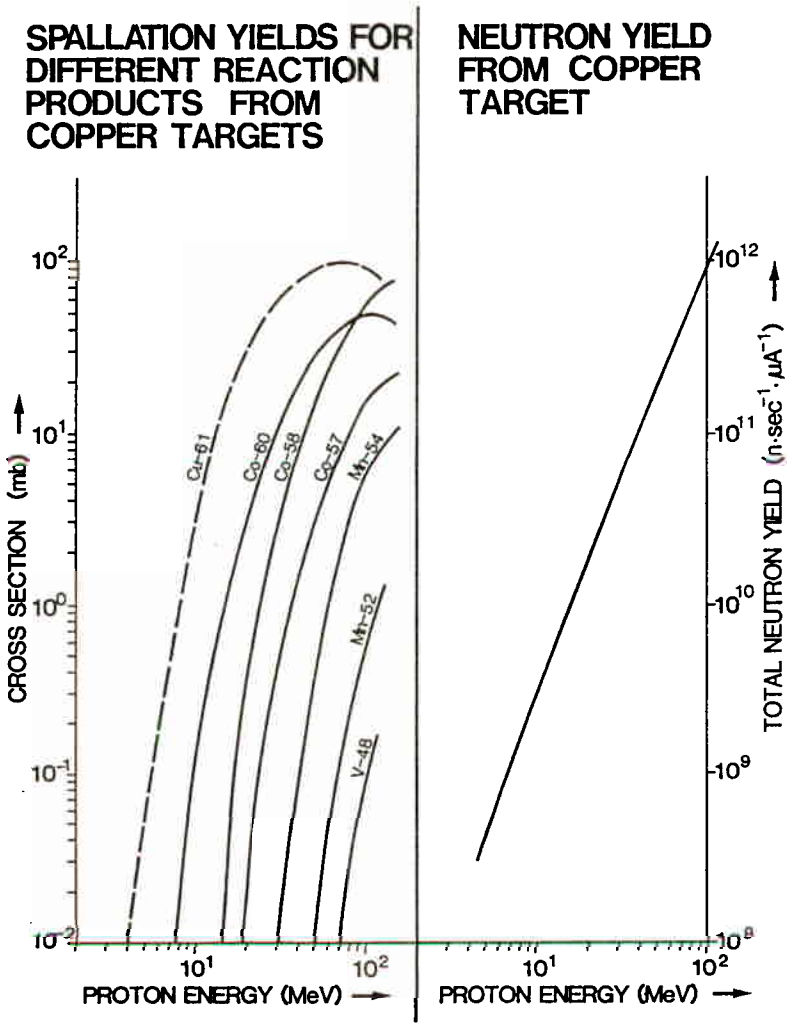
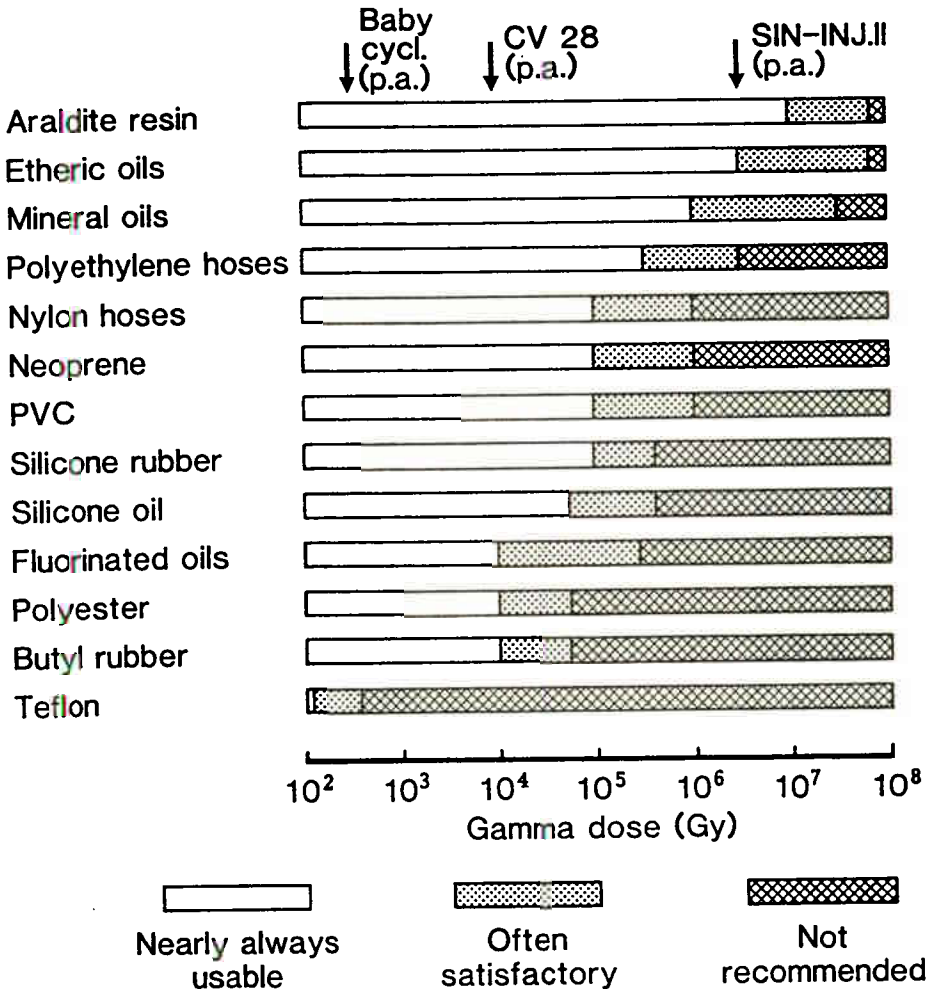


Figure 4

RADIATION EFFECTS IN PLASTICS

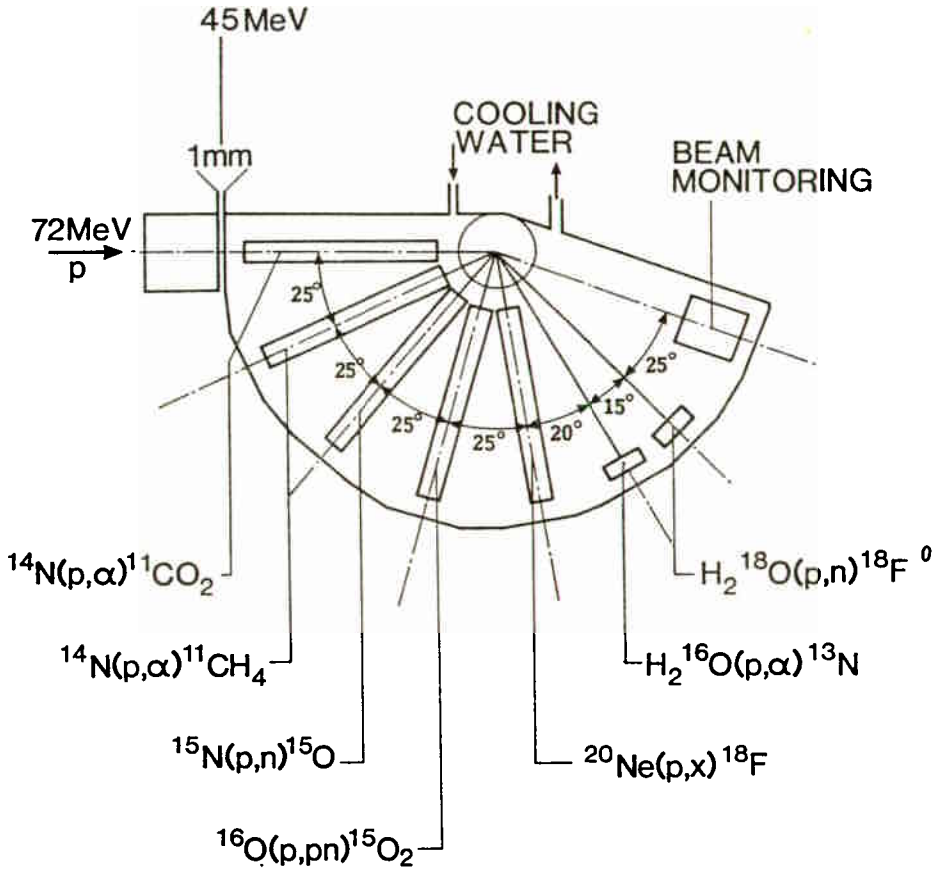
(CABLE INSULATION, HOSES, OILS, THERMOSETTINGS, ETC.)



(CERN Data, 1982)

Figure 5

TARGET "WHEEL"



TARGET "SPOKES"

Figure 6