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TARGET STATIONS AND BEAM DUMPS FOR THE CERN SPS

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Summary

The design of the absorber blocks for internal and external dumping of the SPS proton beam is discussed. In addition, the external target stations for slow and fast extracted proton beams are described.

1. Introduction

A proton beam of 10^{13} protons per pulse (ppp) at 400 GeV/c has a kinetic energy of 640 kJ. It is therefor essential to dispose of the beam in a well controlled way when the beam is not used for target irradiations. For this purpose, an internal beam dumping system is installed which deflects the beam in one revolution onto an absorber block [1]. Furthermore, a movable absorber block has been provided at the beginning of each of the two beam transfer channels to the experimental areas.

For normal exploitation of the SPS, all protons are extracted by slow resonant, fast resonant and fast extraction and channelled to external target stations. At present, five out of six installed target stations provide during each SPS pulse secondary particle and neutrino beams to the West Experimental Area.

2. Beam absorber blocks

The highest rate of energy deposition in the core of an absorber block occurs when the proton beam is dumped in either one SPS revolution with a duration of 23.1μs in case of either internal beam dumping or fast extraction, or during fast resonant extraction with spill durations of about 1 ms. This causes a practically adiabatic heating since the thermal diffusion times of metals are longer by at least one order of magnitude. The development of the nuclear cascade in aluminium and copper has been calculated with a Monte-Carlo program and the resulting temperature and thermal stress distributions have been analysed [2,3]. For a gaussian beam of 10^{13} ppp at 400 Gev/c, with a beam radius of 2 mm (corresponding to 2.25 standard deviations), the maximum temperature rise is 300 °C for aluminium and 1330°C for copper. Measurements for both metals show reasonable agreement with these Monte-Carlo results [4]. Thermal stress beyond the elastic limit can only be avoided by a beam blow-up to a cross section of at least 150 mm^2 for aluminium and 1700 mm^2 for copper.

The absorber block for internal beam dumping has a core with a diameter of 273 mm and a length of 4080 mm. The first 2520 mm is made out of the aluminium alloy Al Mg Si 1 and the remainder out of copper alloy Cu Cr Zr. An opening through the full length of the core permits the passage of the circulating beam. The latter is deflected downwards onto the front face of the core when it is dumped and spread over about 200 mm^2 through a simultaneously applied $\pm$ 10% oscillation on the constant vertical deflection and a horizontal sweep. Both the aluminium and the copper parts are cooled through deep-drilled water channels. The core is embedded in two half cylindrical cast iron shields with an outer diameter of 960 mm and a length of 4700 mm. These shields are cooled via stainless steel tubes cast into the iron. Fig.1 shows the assembly of this type of absorber block.

The absorber blocks for external beam dumping are moved horizontally in and out of the beam line and have therefor no opening for the passage of the beam. Their core consists of either two consecutive cyclinders with a diameter of 273 mm and a length of 2000 m in copper alloy or, alternatively, of one cylinder in aluminum alloy and one in copper alloy. These cylinders are water cooled and surrounded by a cast iron shield as described above. The absorber blocks have a weight of 22 tons.

3. Target Stations

3.1 Targets. In general, a pencil-like shape of the external targets is required in order to reduce the lateral source size for the ensuing secondary beam lines. Sometimes, this condition can be relaxed to the use of a thin plate as a target. Target materials of low atomic number are preferred in order to produce the largest number of secondaries per interacting proton. These materials, fortunately, have also the lowest energy deposition density per incident proton.

Monte-Carlo calculations of the energy deposition density distribution show that for the adiabatic heating by one fast or fast resonant extracted proton beam pulse, focussed to a waist of 2 mm diameter, the maximum temperature rise in the centre of the target exceeds the melting point of all metals except beryllium [5]. For the slow extracted beams with spill times longer than 50 ms, the use of aluminium is also possible.

The dynamic thermal stress waves created in the in the target as a result of the delay in its thermal expansion compared with its rapid heating by a fast or fast resonant extracted beam can be reduced to values below the yield strength by a subdivision of the target length into several parts [3,5]. The quasi-static thermal stress due to the radial temperature gradient, however, exceeds the elastic limit even for beryllium. Only experience will reveal the maximum beam intensity a repeatedly overstressed beryllium rod can sustain. For spill durations longer than 50 ms, the quasi-static thermal stress becomes negligible.

3.2 Beam monitors. All target stations are equipped upstream and downstream of the target with secondary emission beam monitors. The upstream monitor measures the intensity of the incident beam, its halo and its horizontal and vertical position. The pairs of split foils for the measurement of the latter permit to steer the beam accurately onto the centre of the target. The downstream detector monitors the yield of secondary particles.

3.3 Design criteria of the target stations. The design of all high-intensity target stations of the SPS is based on a "hot zone" of limited volume, which only contains passive elements like the target container and some of the beam monitors. This volume is completely surrounded by a cast iron shield in order to reduce the radiation level in the target areas during operatiion and to confine the induced radioactivity. Any movement of the target container and the beam monitors is made from the outside of the shield via rigid supports which traverse the shielding through slots. This avoids limitations in the choice of sufficiently radiation hard electrical components and permits human intervention for alignment and quick repair or exchange of faulty equipment outside the shielding.

The access to the hot zone is obtained by a remotely controlled horizontal displacement of the movable top shielding. All exchanges of target containers or beam monitors are made with overhead cranes which either have or can be fitted with a remote control. The new elements automatically find their position via self-centering devices.

3.4 The target stations for slow extracted beams. A vertical cross-section of a typical target station for slow extracted beams is shown in fig. 2. A new type of beryllium and aluminium plate targets "with grooves", as shown in the insert of fig.2, is made as an approximation of the required pencil-like target shape. The deposited heat is laterally conducted towards the fins attached to the support frame of the target plate. These fins are cooled by forced air convection. Five targets are available per target station. They are stacked vertically at a distance of 40 mm from one target to the other[6].

The target container and the two beam monitors are supported from above by a common frame whose vertical position can be remotely adjusted with respect to the beam. An independent vertical movement of only the target container in discrete steps defined by a cam-wheel mechanism permits the selection of each of the five targets for irradiation. Fig.4 shows a photograph of two combined target stations of this type, which each feed two secondary particle beams for counter experiments.

3.5 The target stations for fast extracted beams. Two target stations with a common cast iron shield feed respectively the wide band and narrow band neutrino beams. Their beryllium targets are irradiated by a fast or fast resonant extracted beam of high intensity at 400 GeV/c. The maximum fast extracted beam intensity to date has been about 6 10^{12} ppp. Each target station has a target container with three cylindrical targets placed horizontally adjacent to one another at a distance of 45 mm.

Each of the targets for the wide band neutrino beam comprises 11 segments of 100 mm length distributed longitudinally over 2000 mm, and have diameters of 3 and 10 mm respectively. This spread of the segments of the thinnest beryllium target leads to an improvemen of the escape probability of the secondaries produced at non-zero angles, e.g. an increase in yield of 20 to 30% is expected for 70 GeV/c pions. The insert in fig. 3 shows schematically the layout of these targets. Those for the narrow band neutrino beam each contain 5 segments of 100 mm length distributed over 550 mm and have diameters of 2 and 10 mm respectively. The rod segments are supported at either end by a 2 mm thick beryllium plate.

The targets are cooled by forced convection with helium gas, after hydrogen the most efficient gaseous cooling medium,directed perpendicularly onto the rods with a velocity of 4 m/s. The gas flow is supplied by a closed circuit which contains a Roots pump of 1000 m^3/h capacity, a heat exchanger and the target container.

Fig. 3 shows a vertical cross section of the wide band neutrino target station. The downstream beam monitor,just upstream of the shielding, and the target container are mounted on the common longitudinal part of a movable horizontal T-shaped aluminium girder. The three ends of the frame protude through slots in the shield at the upstream end and at the two side faces of the station, where they are supported by motor driven positioning mechanisms. These permit a remote alignment of the target with the beam as well as a selection of the target to be irradiated. The latter implies the use of three pairs of vertical split foils in the upstream beam monitor to enable the horizontal steering of the proton beam onto the selected target. The downstream beam monitor, whose position is not critical, is placed in a fixed position on the downstream shielding.

The layout of the target station for the narrow band neutrino beam is similar to that of the wide band station. The two proton beam branches at the position of the targets have a horizontal distance of 902 mm and a difference in height of 474 mm. The T-shaped support of the narrow band station is therefore sufficiently displaced to pass through slots in the common shield below the T-shaped support of the other target station. A photograph of the upstream side of these target stations is shown in fig. 5.

References

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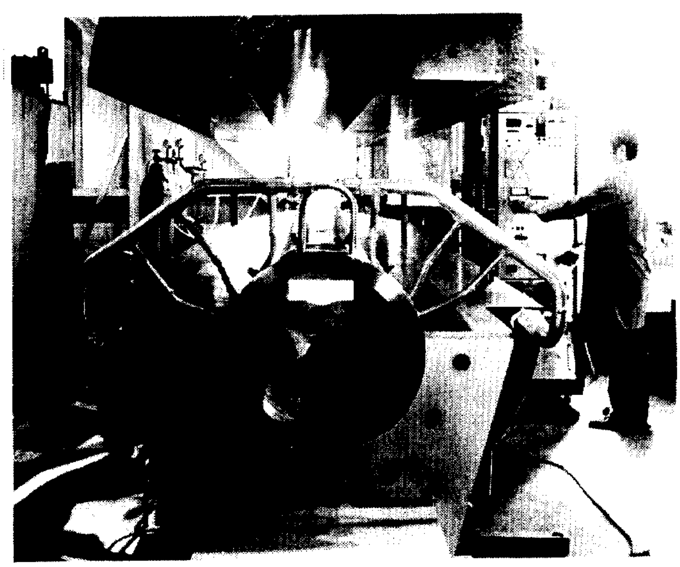

Fig. 1 The assembly of an absorber block for internal beam dumping.

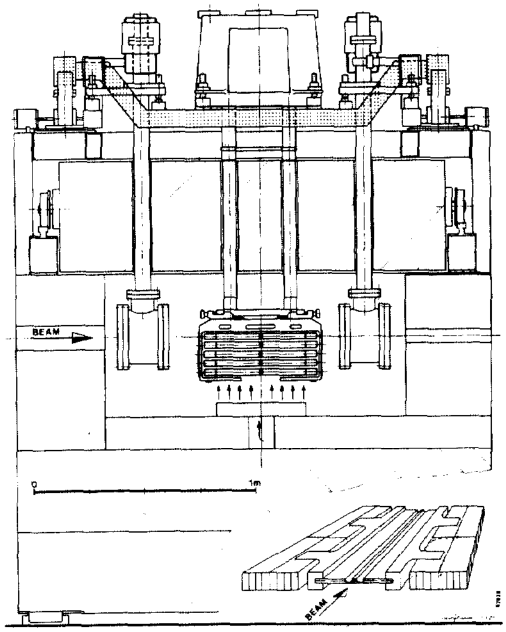

Fig. 2 The vertical cross section of a target station for slow extracted proton beams The target container and the beam monitors are rigidly suspended from an adjustable support above the mobile top shielding.

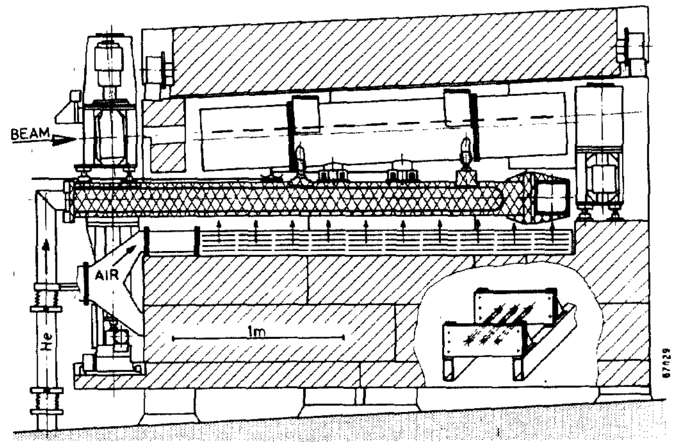

Fig. 4 The vertical cross section of the target station for the wide band neutrino beam. The upstream beam monitor, just outside the shield, and the target container are mounted on a common horizontal T-shaped aluminium girder. The downstream monitor is placed directly on the cast iron shield. The top shield is mobile to permit remotely the removal of the elements in the hot zone.

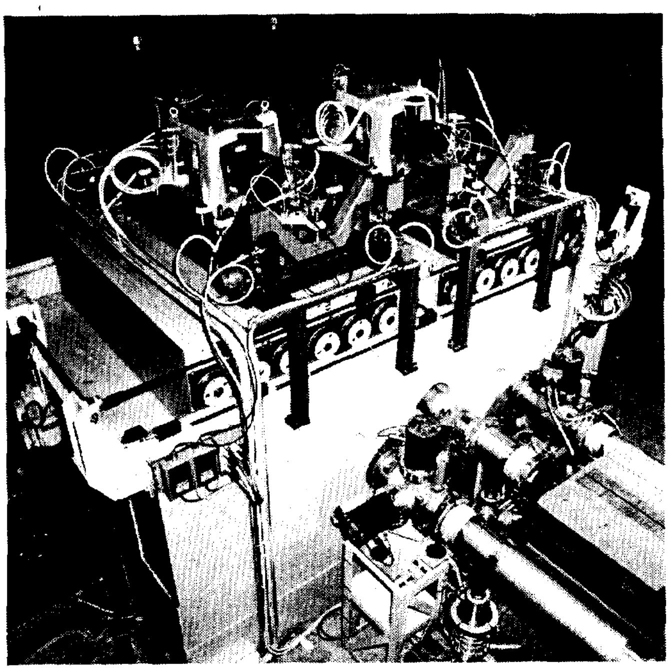

Fig. 3 An upstream view of two combined target stations for slow extracted beams. The two extreme proton beam branches each irradiate a target inside the cast iron shield which each feed two secondary particle beams. The central proton beam branch traverses the shielding towards a third target station further downstream.

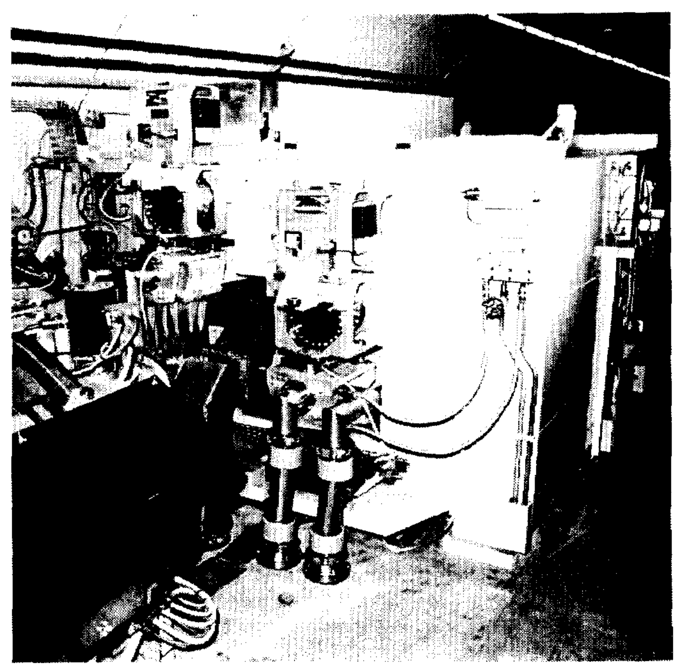

Fig. 5 An upstream view of the twin target station for the wide band (left)and the narrow band neutrino beams (right).