

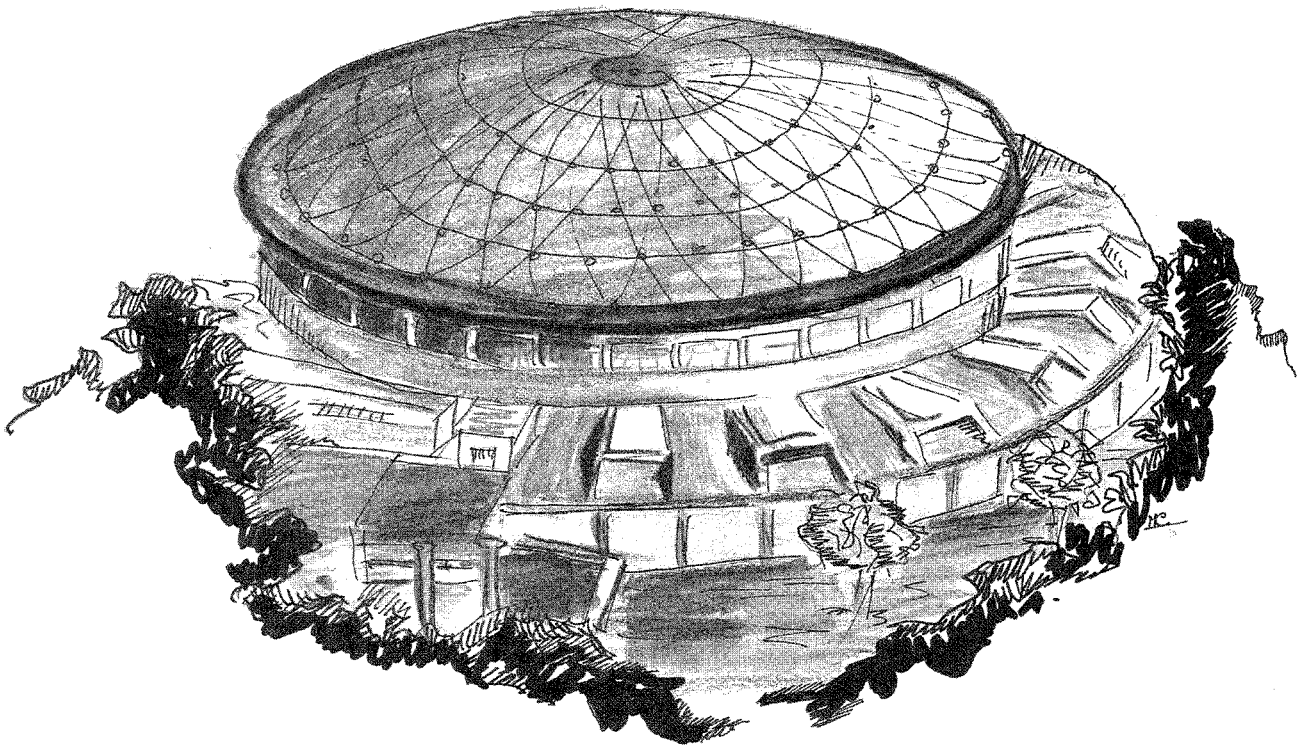


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P. Benvenuto, R. Casaccia, M. Gatta, E. Gragl, I. Laakso, F. Masi, A. Pecchi
INFN - Laboratori Nazionali di Frascati, P.O. Box 13, 00044 FRASCATI (Rome) Italy

ABSTRACT

We refer details on the construction and operation of a milling machine to obtain the readout pads on a printed circuit boards for the LST (Limited Streamer Tubes) particle detector for the ZEUS Experiment.

1. - INTRODUCTION

A new collider HERA is in construction at DESY, Hamburg. The colliding particles will be 820 GeV protons against 30 GeV electrons. Our group is involved in the design and construction of the muon detector in the forward (proton) direction. The iron muon filter will be toroidally magnetized, and the detector will have both functions of precision tracking and triggering based on magnetic stiffness of muons. This last function is obtained with a LST detector, consisting in four roughly circular 6 m diameter detector planes. Each unit is assembled in a double layer of LST tubes of $8 \times 1 \text{ cm}^2$ section. For the inductive readout a polar coordinate geometry has been chosen. The ways of obtaining suitable readout pads was investigated. Mechanical milling from 1.6 mm printed circuit boards ($G10+2 \times 30 \mu\text{Cu}$) proved to be a practical solution (Fig. 1).

A fullsized prototype of 1 quarter of the detector plane was fabricated and tested. The necessary milling machine which would be needed to the job in hand was thus outlined.

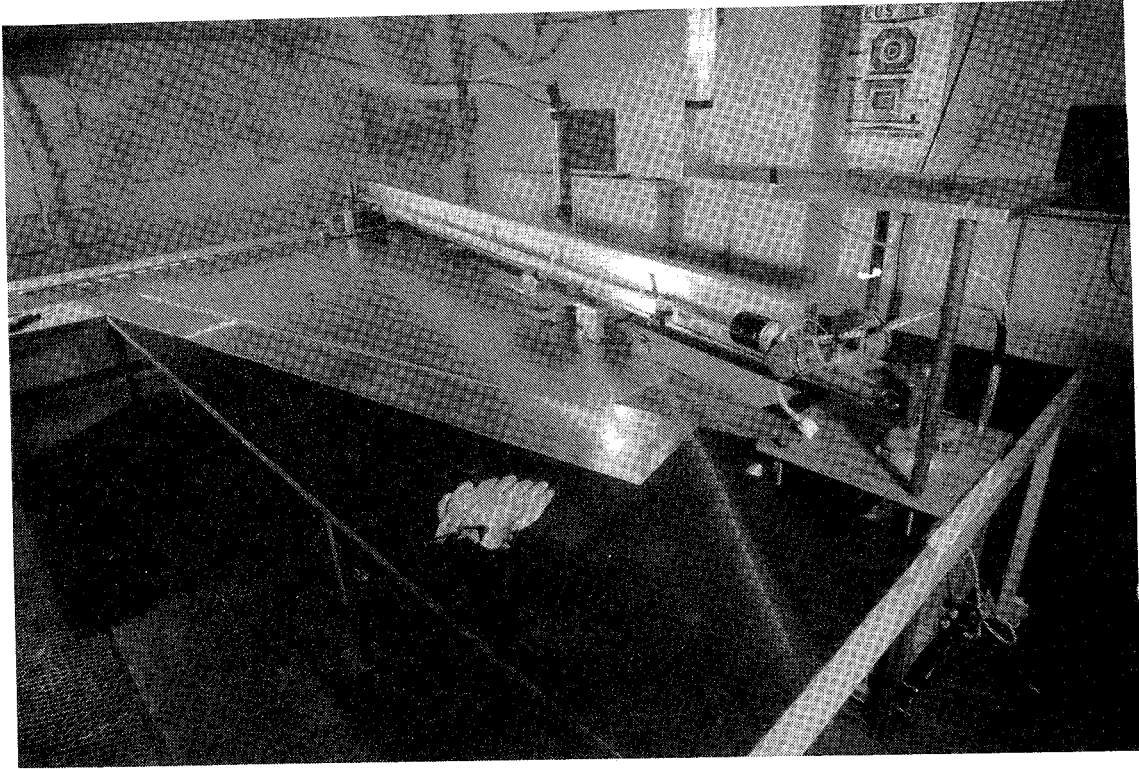


FIG. 1 - General view of the milling machine.

2. - MECHANICAL CONSTRUCTION

The working table of roughly 3 x 4 m irregular shape is made from 20 mm marine plywood, with a welded rectangular steel tube support structure below. The table plane is attached at roughly 1 m grid points with pushing and pulling screws, which were used to adjust the planarity to within 1 mm. The top is covered with a 5 mm neoprene layer, and the gaps between the support structure and the top are filled with a hardening plastic foam to dampen the vibrations. The milling head, a Bosch grinding handtool, is attached to a basculating plate. The wolfram steel milling tool is $\text{\O} 40$ mm 1 mm wide, rotating at 7000 T min^{-1} . The milling depth is regulated by a feeler finger at a distance of 1 cm from the working position (see also ref. 1). This depth is about 100μ , the copper film being of 30μ thickness. The milling assembly can be raised and lowered with a pneumatic actuator.

The milling head runs along a 4 m long beam, supported at its ends, at a gimbaled fulcrum (origin of the $r-\phi$ system) and the azimuthal chariot, see Fig. 2. The precision element is a rectified $\text{\O} 30$ steel bar, bolted to a T section aluminium profile. The rigidity of the beam is given by a rectangular section Al extrusion, epoxied to the T profile. The straightness of the beam was adjusted while the glue bound was made, both in the horizontal and the vertical plane. The amount of flexure due to the milling head fixture weight at the beam midpoint was also compensated by prestressing.

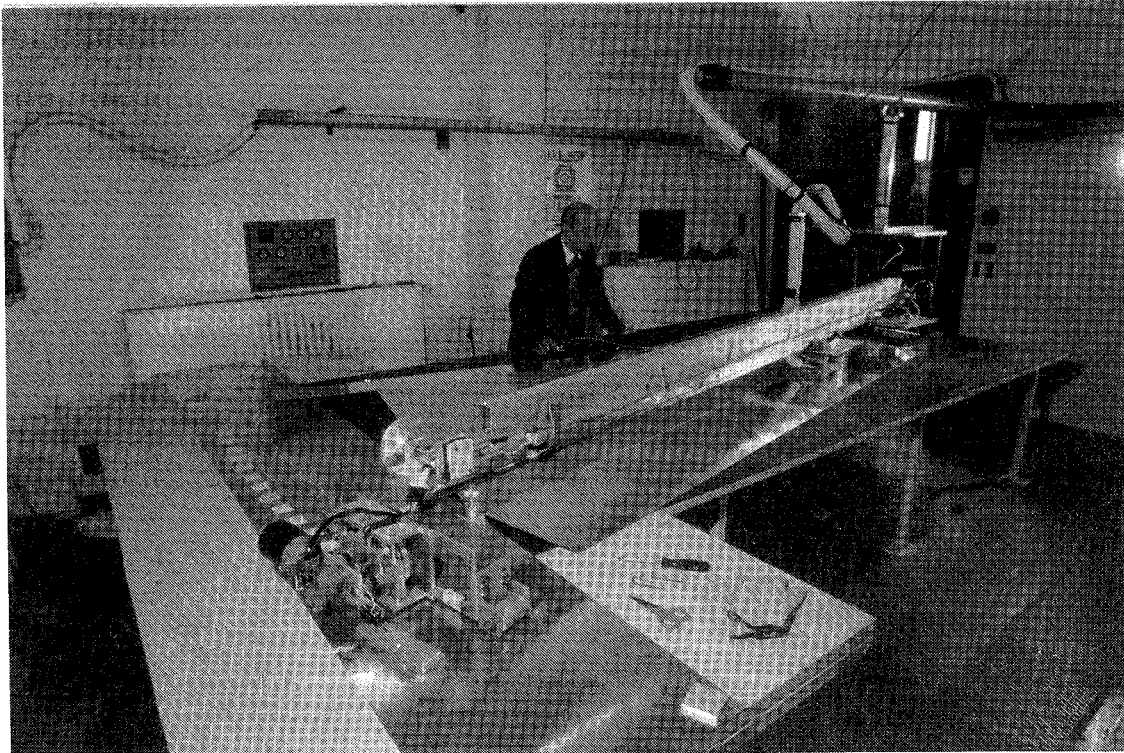


FIG. 2 - Azimuthal chariot details.

The milling head moves along the steel cylinder guided by two circulating ball sleeves, and a rolling ball cushion leaning on the table. The support plate is split into two swiveling parts so that the milling head locks into two positions, for milling the radial and circular grooves.

By experience, it was deemed unnecessary to hold down the double copper plated board by suction. The 1.6 mm G10 board was obtained from Ditron SpA (Novara).

In order to keep the correct milling depth, and also for the working health reasons, the milling tool is enclosed within a box, connected to a powerful aspiration-filtering plant.

3. - THE CUTTING HEAD MOVEMENTS

In order to make the final adjustments in the machine, a theodolite was mounted above the fulcrum. Thus, the straightness and radially of the cuts was verified.

The readout strips are $2\pi/16$ circle sectors, with inner and outer radii of about .8 and 3 m respectively. Due to the geometry of the cuts, a simple pin-latch system was chosen to fix the working coordinates. For the positions of the circular grooves we fix on the radial beam a bar with positioning holes for the pin latch. The 19.0 mm pitch was obtained in a jig boring machine. The positioning holes on the working table which define the radial grooves were drilled directly with a fixture attached to the chariot. The drilling was done under observation with the theodolite, to produce the $2\pi/256$ angular pitch.

The milling head movement is achieved with 24 V DC permanent magnet motors of .5 kW with a worm wheel reduction gear box incorporated.

The radial movement is transmitted with a steel cable loop. The azimuthal motion is actuated with a spring loaded traction wheel in the chariot.

A DC power and command system for the motors was built for other applications in our group, and proven reliable in use. The system consists of three blocks: the three-phase rectifier unit (schematic Fig. 3), the bipolar Dc servo-amplifier (Fig. 4), the command logic box (Fig. 5). When cutting the circular grooves a constant linear speed is maintained, through the sensing of the milling radius with the potentiometer RXX coupled to the radial movement.

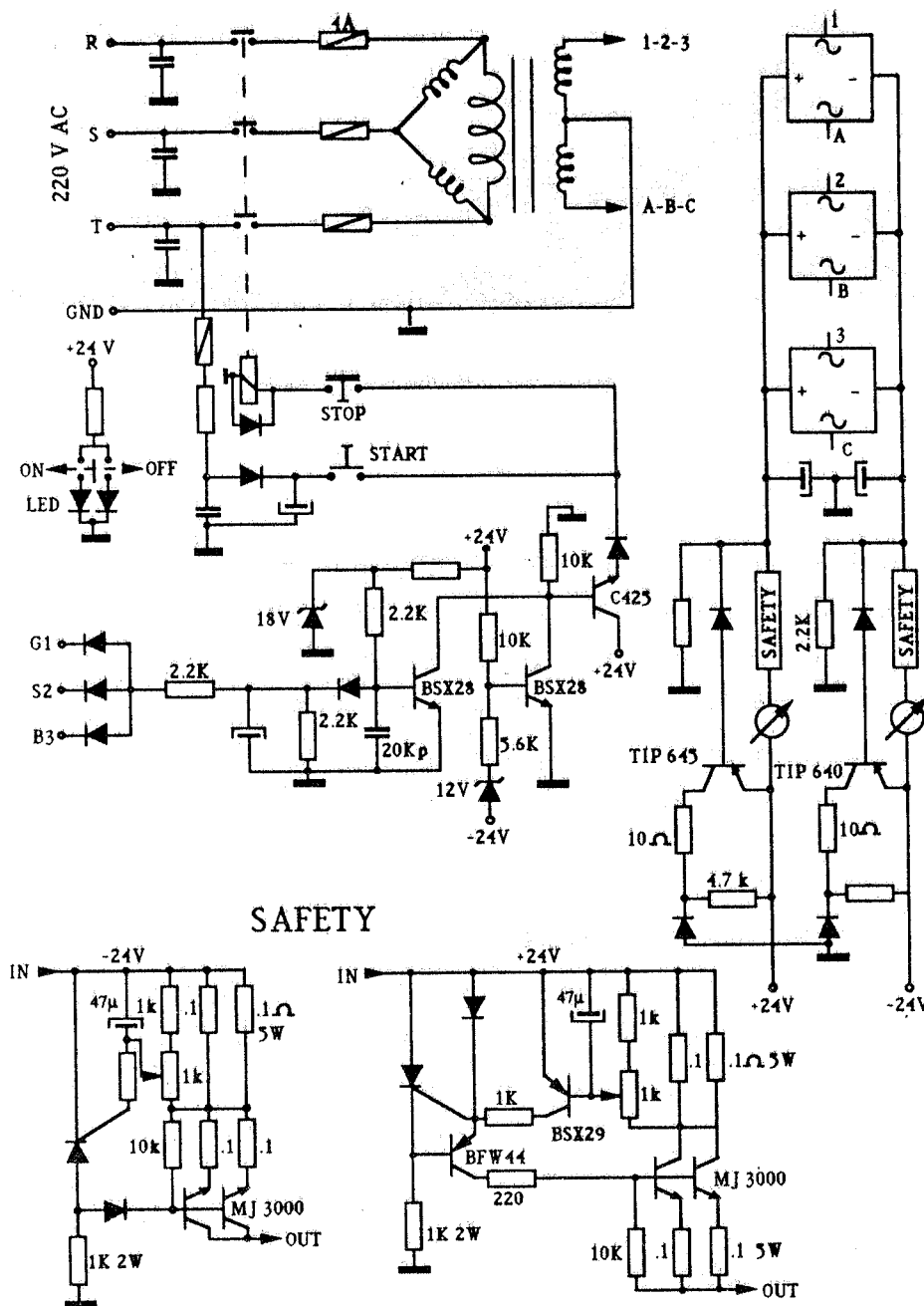


FIG. 3 -Triphase DC power source 24-50 V/50 A.

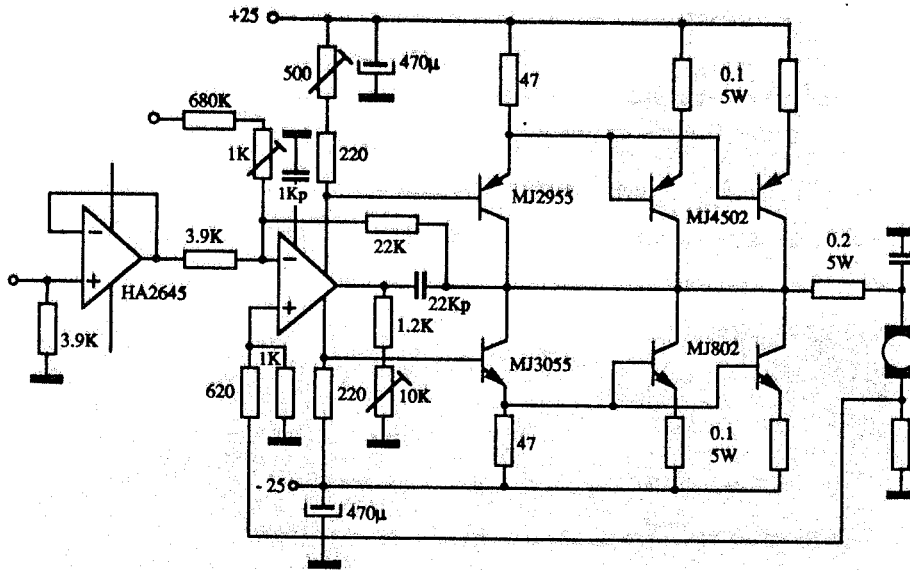


FIG. 4 - Bipolar DC motor power amplifier for 24 V/5 A.

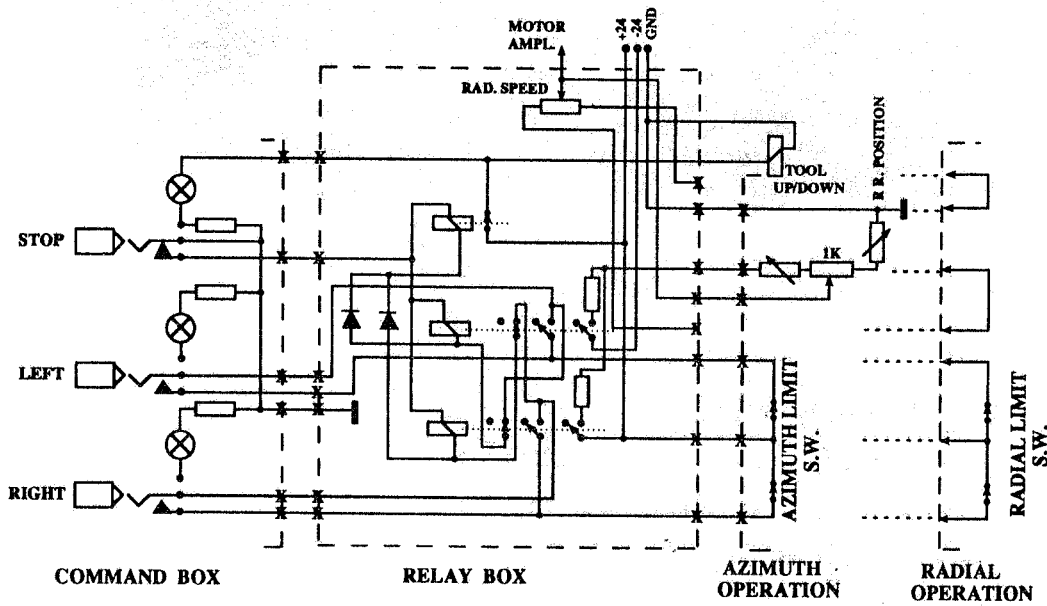


FIG. 5 - Command logic unit for actuating switches and speed-direction selection.

4. - OPERATION AND PERFORMANCE

The start signal for cutting is given manually, stop being given by a limiting microswitch, or emergency manual. These signals also actuate the tool down-up commands.

The linear cutting speed of about 25 cm/sec is used. The edges of the 1 mm groove are reasonably clean as observed in microscope. See Fig. 6. The quality of the cut turns bad at about 1 m/sec speed.

The total length of groove to mill is about 18 km on 256 sector pieces, divided in half between the radial and circular types.

In the same moment that the coordinate system was fixed on the working table, also positioning pin holes were established. For each sector piece blank the positioning is done against these pins. These are then removed and substituted by strips of the same 1.6 mm thickness to function as positioning stops. The production rate is about 10 sector sheets per work day.

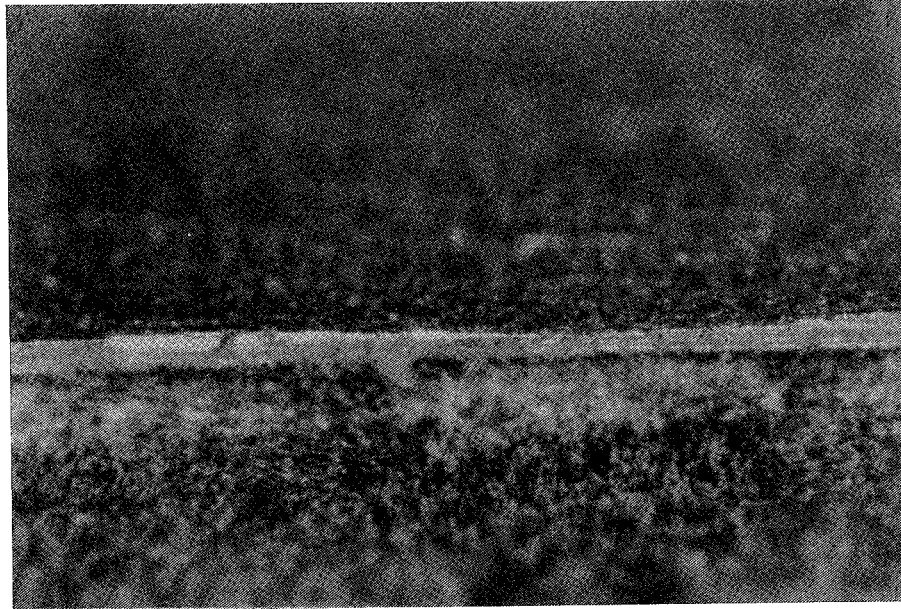


FIG. 6 -Micro photograph of the milled groove.

5. - ACKNOWLEDGEMENTS

The basis of the milling machine described here is the one constructed at INFN-Bari for the ALEPH experiment, see ref. 1. Besides of the thanks due to permission to use pieces of equipment, discussions with A. Clemente are acknowledged.

In the design of the motor amplifier, contributions at Dr. Fabbri and L. Sangiorgio are acknowledged.

The contribution of A. Ceccarelli and M. Troiani in alignment and metrology during this work is acknowledged.

To E. Gradl and A. Pecchi going to retirement at the time of publication of this work special thanks are due for long years of collaboration with us and others from the LNF.

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