CURRENT ALIGNMENT TOPICS AT CEBAF

GEORGE BIALLAS

Continuous Electron Beam Accelerator Facility

Newport News, VA.

Overview

The Continuous Electron Beam Accelerator Facility (CEBAF) is a 4 GeV electron accelerator for the Nuclear Physics Community at Newport News, Virginia.* The machine configuration of this accelerator, due to be completed in 1993 and shown in figure 1, is a recirculating linac device that starts with an injector at 50 MeV and continues into a 0.4 GeV linac. The first recirculation is accomplished by arc magnets which bend the beam around 180° in the uppermost of five beam lines, directing the beam into another 0.4 GeV linac. The beam is similarly bent back into the first linac using another recirculating arc. The process continues, the beam gaining energy and cycling to lower arcs until five recirculations have taken place and the beam is at 4 GeV. The beam may be extracted at any of the four intermediate energies or the final energy and directed to all of the three end stations.

Each linac consists of twenty tanks 8.25 m long placed at a pitch of 9.6 m. Each tank, called a cryomodule, contains eight superconducting accelerating cavities 0.5 m long immersed in a bath of liquid helium at 2 K. The tanks are separated by a region of room temperature beam pipe with a quadrupole, beam position detector and two corrector dipoles placed on a common girder. The entire linac is contained in a tunnel 3.96 m (13 ft) wide by 3.05 m (10 ft) high; whose floor is 7.7 m (25.25 ft) from the surface, the tunnel floor slab is poured onto a rock-like material made of partially cemented shells known as marl. The tunnel concrete is enclosed in a membrane of vulcanized rubber and backfilled with no attempt to prevent complete immersion in the ground water.

The recirculating arc tunnels are the same size as the linac tunnel. The recirculating arcs undulate either side of an average 80.6 m radius in the semicircular tunnel. The stand

* Sponsored by the Department of Energy and the State of Virginia

with quadrupoles shown in the illustration of figure 7 is shown in the most extreme aisle squeezing position.

The element count is shown in Table 1. In general, all quadrupoles are supported on a girder along with their respective beam position detectors, corrector dipoles and vacuum apparatus. The quadrupoles are aligned on the girder with a three point support with respect to the beam position detector. Corrector dipoles are similarly positioned on the girder. The girder is then positioned on a three point support system described later. All other elements, such as the major dipoles, and septa are placed on their own three point supports.

Figure 2 shows the top and side views of the injector line consisting of 2 1/4 cryomodules, the relatively sparse positioning of the magnetic elements, and the intersection of the arc magnets (top view only).

Figure 3 shows the continuation of the injection chicane, the recombiner for the four recirculation arcs (at the injection end, five arcs are at the opposite end) and the start of the first linac.

Figure 4 shows a representative portion of the first arc (note the five beam lines). Note, quadrupoles have been placed over one another so common stands may be used for their girders. The stands for the dipoles will be slightly more complex.

Figure 5 shows a typical warm region stand intended for use between cryomodules. It illustrates the typical magnet placements on the girders and placement of the typical three point supports known as cartridges.

Adjustment Mechanisms & Stands

The cartridge, shown in figure 6, is based on a CERN design with simplification to accommodate our lighter loads and our access to the bottom for adjustment. We intend to place dial gauges on all cartridges to measure the six degrees of freedom while adjusting and locking. The cartridges will be placed in a pattern of two at the upstream end and one at the downstream. The two at the upstream will have cap adjusting screw orientations along the beam axis at the rear and perpendicular to the axis at the front. The cartridge at the downstream end has adjustment perpendicular to the beam axis. In this way, all degrees of freedom are constrained and adjustable.

This cartridge is also planned to be used in the recirculating arc stands shown in figure 7. Here a series of five quadrupoles in the first arc is shown. The stand has a single adjustor for the vertical direction at the base and a flexplate attachment to the tunnel at the top to accommodate vertical movement from adjustment and other motions. This feature allows direct adjustment for tunnel settlement of all five devices.

Tolerance Budget

Our tolerance budget is shown in Table 2. This is the total error budget and not only includes error in the placement of elements on the local beam line, but ambiguity in knowledge of the magnetic axis and error in fixation of the fiducials. The local beam line is defined as ± 25 m from the element. The DIMAD analysis which was used to develop these specifications assumed a Gaussian distribution with the tails truncated at ± 2σ. (Smoothing of the beam line is assumed.) The accelerator remains robust up to twice these tolerances. This additional latitude is a provision for medium term settlement.

Alignment and Survey Plans

Our plans are to maintain both vertical and transverse monument networks in the tunnel which are not based on surface monuments. Provision has been made for going to such a network by means of four penetrations to the surface at the arc tangents and one in each end station.

We plan to use Geonet for data collection, storage, error check and analysis. We will use levels and inclinometers for survey and alignment of the vertical dimension. The transverse dimension will be surveyed with electronic theodolites and aligned with electronic dial gauges keyed to an electronic notebook. The ME5000 distance meter will be used for all distances down to 5 m. Jig transits and scales will be used for special cases. Fiducials on elements will be the stamped or machined surfaces that accept a fixture with exchangeable tooling balls and targets. Special elements will have integral tooling ball/target sockets.

Both the quadrupole and the dipole magnet measurement systems are built upon surface plates. We intend to verify the position of the fiducials, the measurement coils, and the pole faces at the time of measurement, by elementary metrology in an integrated operation.

Table 1

Element Counts

MAGNETS:	
Corrector Dipoles (< 32 cm x 1 kG)	1047
Major Dipoles (> 1 m x 1 kG; < 3 m x 7 kG)	390
Quadrupoles	707
Sextapoles	96
Septa	26
Lambertson SEPTA	1
TOTAL:	2267
CRYOMODULES	42 1/4 (338 Cavities)

Table 2

Tolerance Budget

Parameter	Tolerance	Comments
σ_x or σ_y	0.2 mm	(Dipole larger but not verified by calculations)
σ_z	5 mm	
σ'_z	10^{-3}	
σ'_x or σ'_y	set by σ_x or σ_y at both ends	for dipoles
Tx' or Ty'	set by $\frac{\sigma_x}{l}$ or $\frac{\sigma_y}{l}$	for quadrupoles
Accelerating Cavity Exceptions		
σ_x or σ_y	1 mm	
σ'_x or σ'_y	4×10^{-3}	

- Tolerance Includes
    - Ambiguity in knowledge of magnetic axis
    - Error in fixation of fiducials
    - Error in placement of element of local beam line
- Local beam line is ±25 m of element
- **Assumes Gausian distribution with tails cut at $\pm 2\ \sigma$**
- Accelerator remains robust up to twice the above tolerances - provision for medium term settlement

[apd.biallas]slacpaper.tex

MACHINE CONFIGURATION — CEBAF

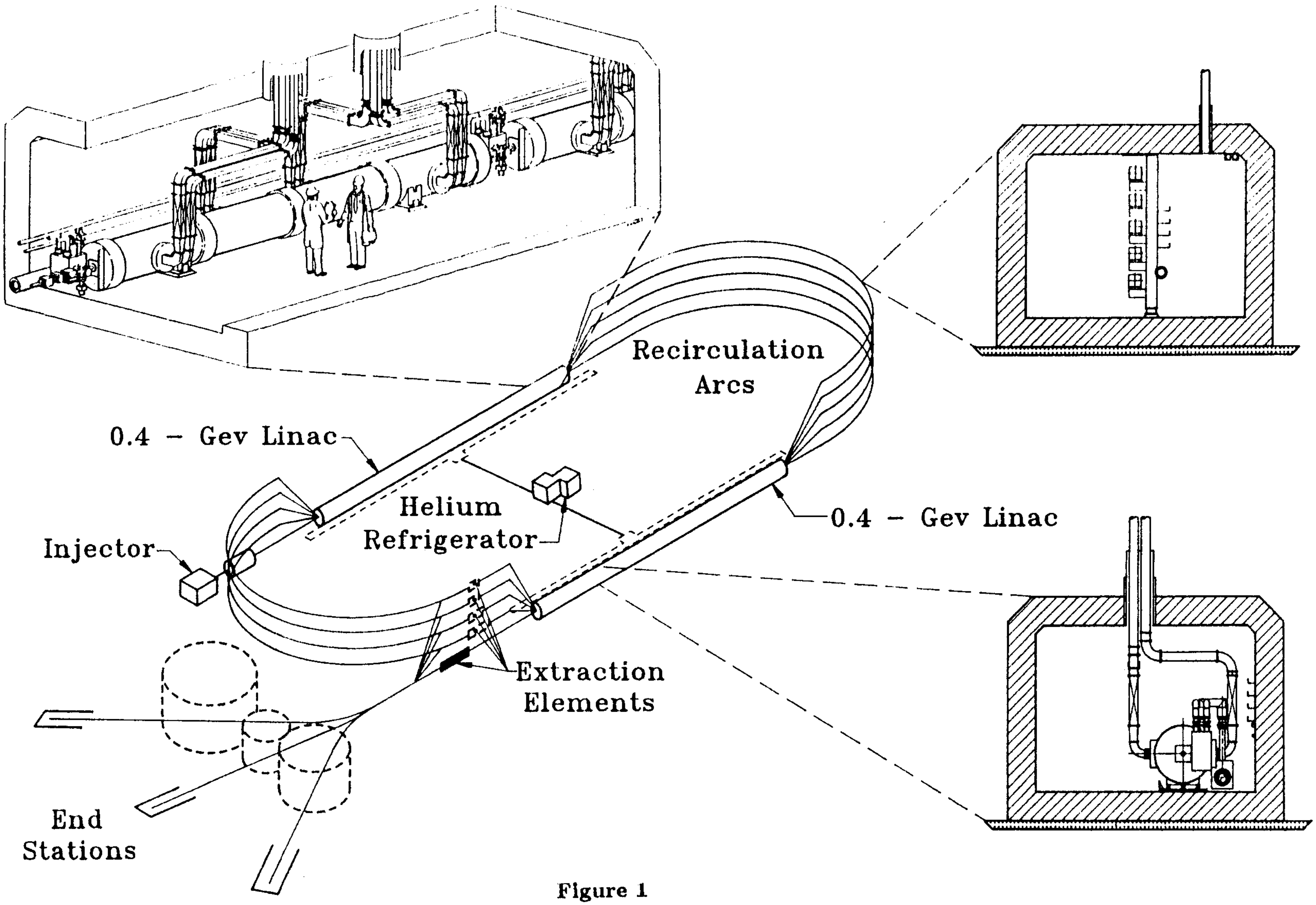

Figure 1

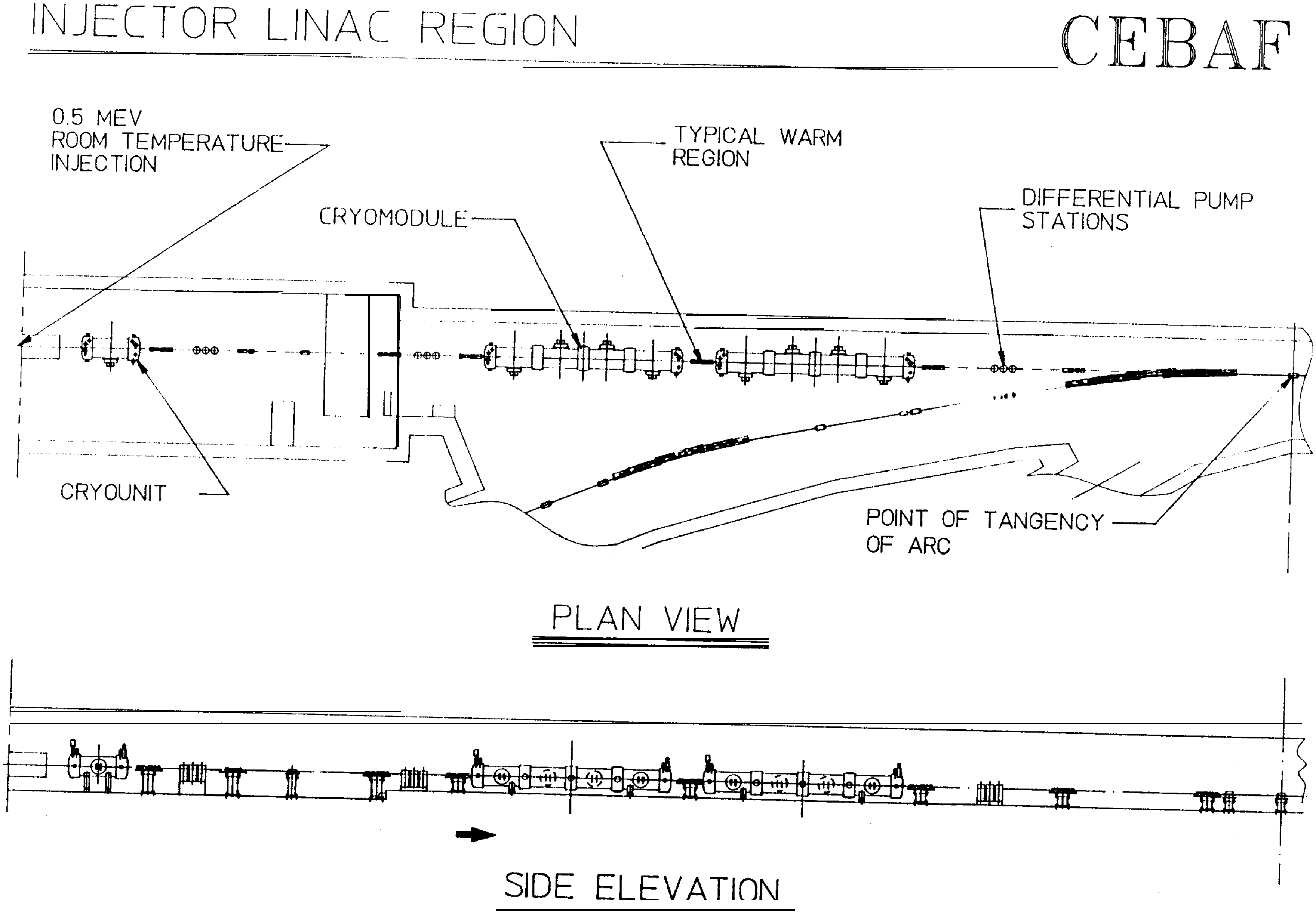
INJECTOR LINAC REGION
CEBAF
0.5 MEV
ROOM TEMPERATURE
INJECTION
TYPICAL WARM
REGION
DIFFERENTIAL PUMP
STATIONS
CRYOMODULE
CRYOUNIT
POINT OF TANGENCY
OF ARC
PLAN VIEW
SIDE ELEVATION

Figure 2

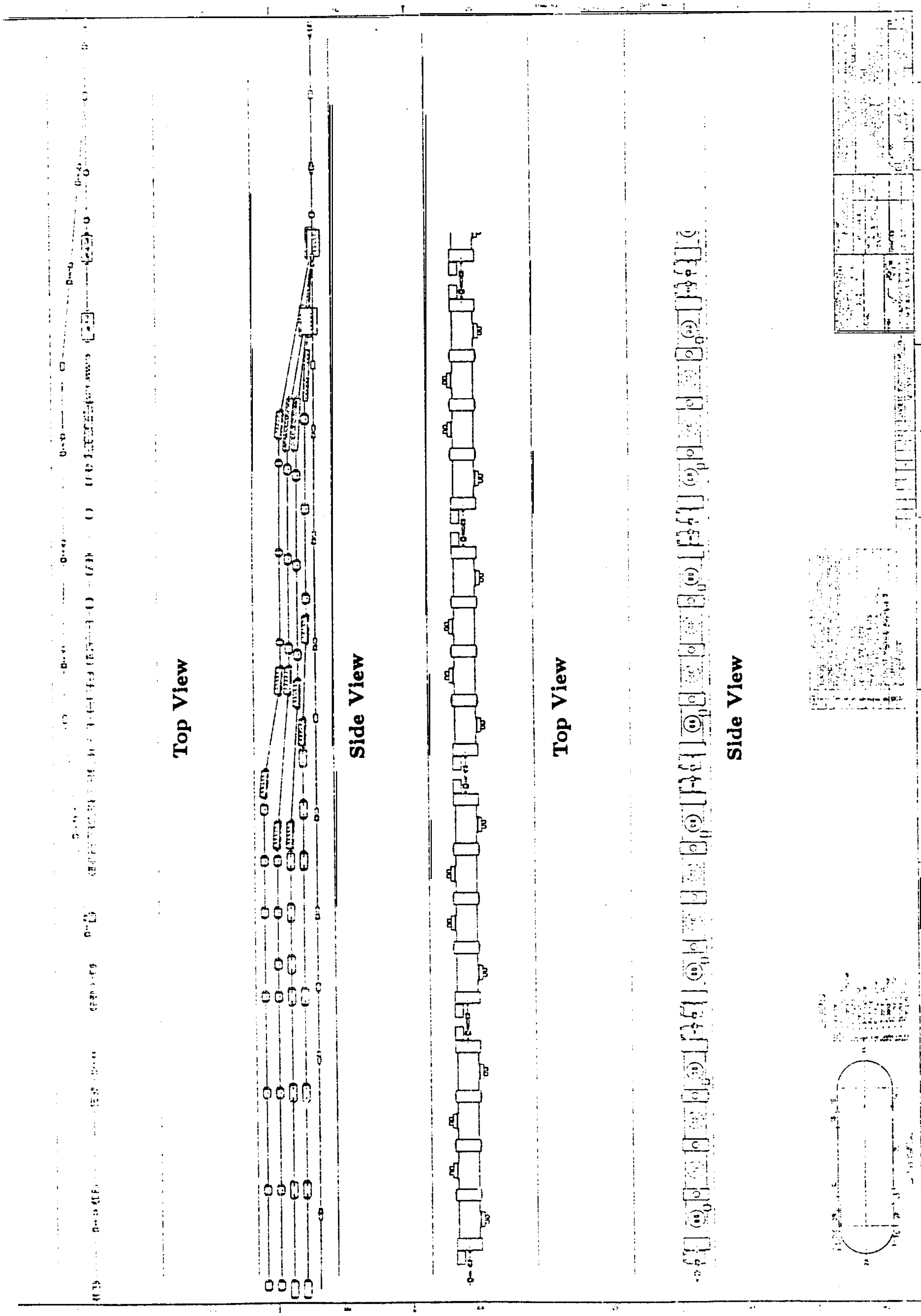

Figure 3

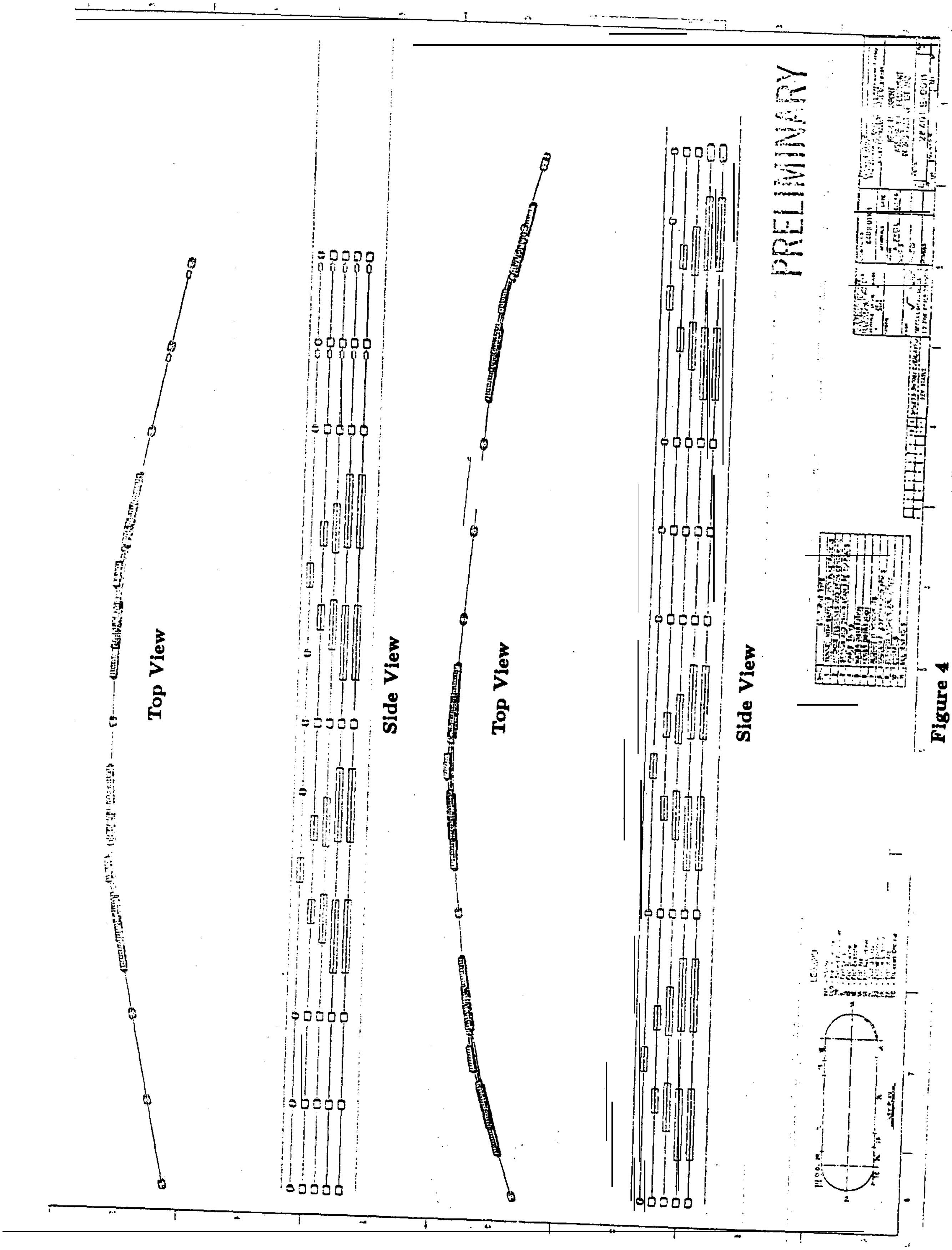

Figure 4

WARM REGION BETWEEN CRYOMODULES CEBAF

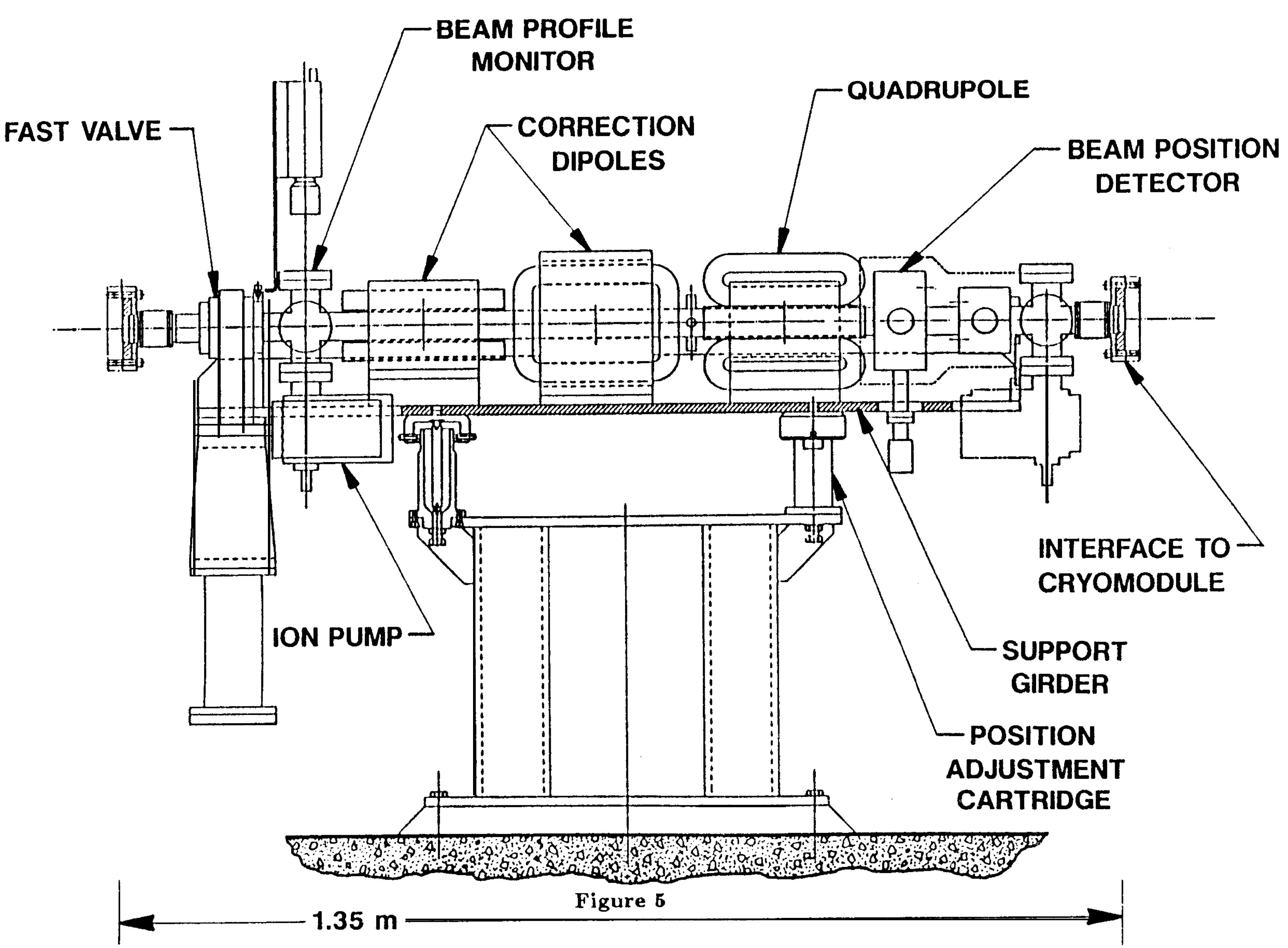

Figure 5

STAND ADJUSTMENT CARTRIDGE

CEBAF

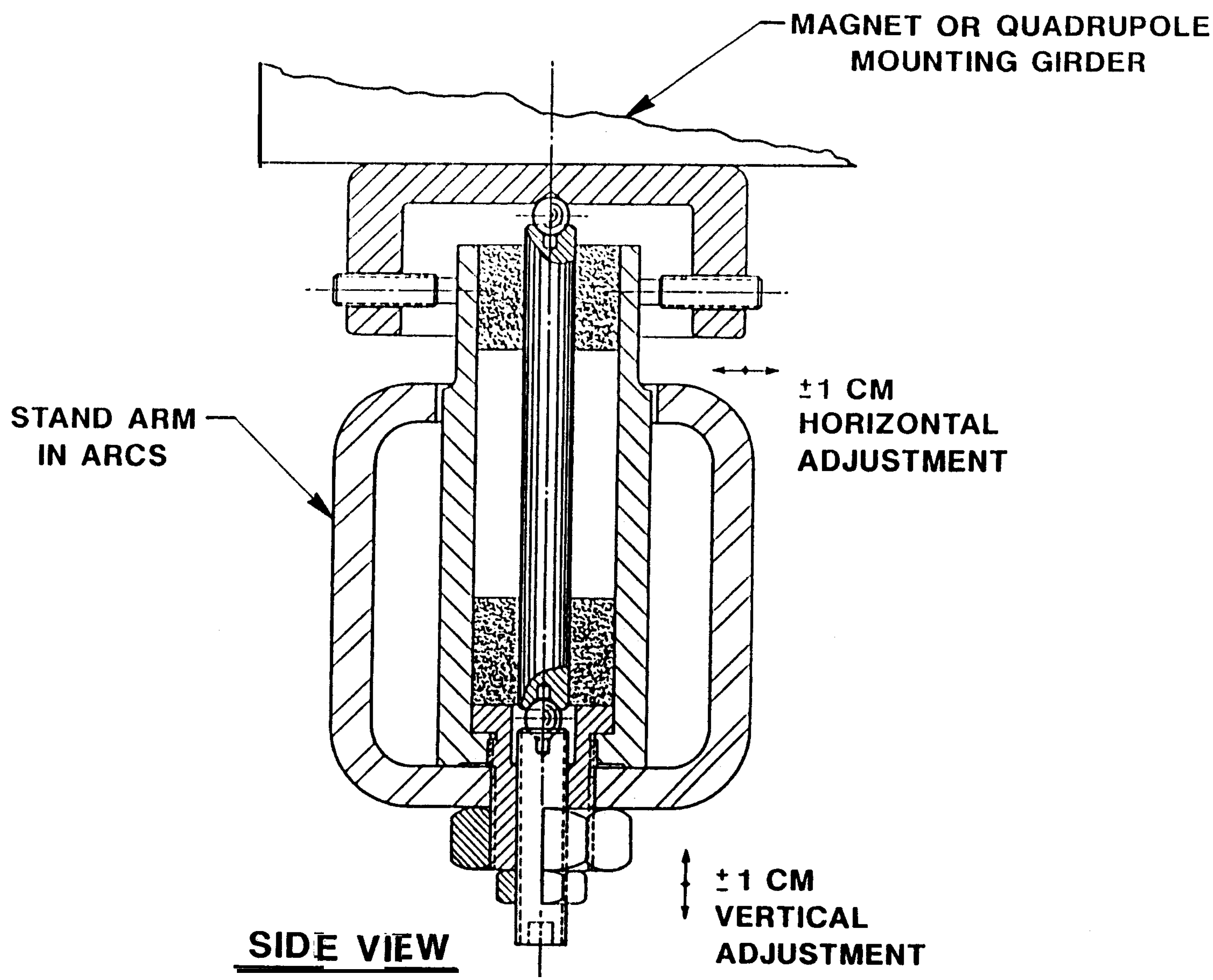

Figure 6

TYPICAL ARC CROSS SECTION SHOWING STACKED QUADRUPOLES

CEBAF

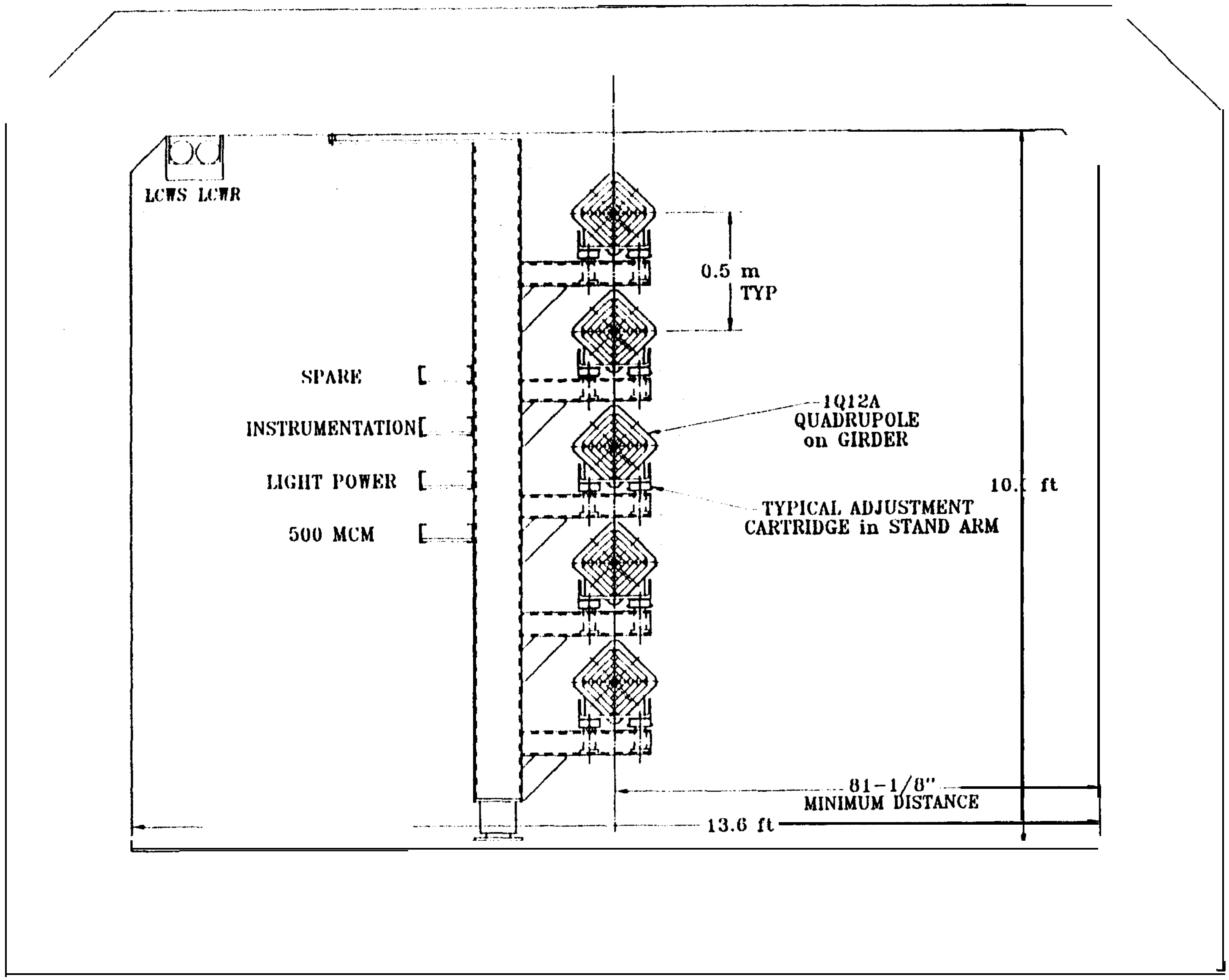

Figure 7