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NEW 200 MeV BRANCH LINE TO BLIP

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Collider Accelerator Department

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AGS DIVISION TECHNICAL NOTE

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I. General

The Brookhaven Linear Accelerator Isotope Production Facility has been operational since 1973. The reliability of the facility is not only related to the value of the facility itself, but also directly related to the performance of the AGS. Since the beam transport line and AGS injection line share the common vacuum system, vacuum failure in the line directly affects the AGS operation. There are other interactions between BLIP line and AGS through the 200 MeV linear accelerator from the ion source to the radio-frequency system, but we are going to limit this note only to the extent of the beam transport system, after acceleration. Most of the vacuum failure is related directly or indirectly to the protons that went off the course of designed transport line. When a significant amount of the proton gets off the course and striking the material, mainly the wall of the vacuum pipe or transport equipment and the system of beam monitoring equipment, and the materials around the vacuum system (especially electrical feedthrough) receive enough radiation caused by those stray protons, material fails and causes the vacuum system to fail. The more dramatic thing to happen is, the striking protons heat the vacuum pipe and raise the temperature of the material to the melting point. Especially when the main body of the proton current goes through the wall of vacuum system, the material melts in a very short period of time.

In the old system, there were other related problems. The optical system consisted of pulsed quadrupoles because of the addi-current from the pulsed quadrupole field. The vacuum pipes were made of stainless steel which has low electrical conductivity. The stainless steel has many undesirable properties in the radiation field, namely, it produces many isotopes which are very long lived. The radiation accumulated in the stainless steel becomes such a problem that maintenance of the system becomes virtually impossible, despite the long cooldown time. In the old optical system, it is practically impossible to eliminate those "halo" protons because of the properties of the radio-frequency systems in the linac. The radio-frequency systems for the accelerating cavities must be compensated for beam loading which amounts to about 2 megawatts when the beam goes through and accelerated in the cavity. The rf servo-system is supposed to compensate for this beam loading problem. In practice, however, there is transient beam error for the first 10 $\sim$ 20 microseconds. Consequently, for the first 10 $\sim$ 20 microseconds the properties of the particles are quite different from the rest of the particles. This might create the "halo" of the beam causing problems. There were proposals to install a fast beam chopper to eliminate this part of the beam, but there were a lot of problems associated with it.

II. Design Considerations

With all the problems mentioned above, the goal of the new BLIP transport system should eliminate all or the most of the problems. The following criteria were used for the base of new design.

a) The transport system is totally momentum recombining so that small radio-frequency error in the accelerating cavity should be compensated.

b) Whenever possible, eliminate the high Z material, like stainless steel, and use minimum number of mechanical flanges.

c) Minimum number of electrical penetration which in the past gave considerable vacuum problem.

d) Vacuum chamber size should be increased to the 8-in diameter pipe instead of 4-in. pipe used in the past. This gives less probability of protons hitting the pipe.

e) The graphite collimator should be placed in a strategic spot to eliminate the possibility of the main body of the beam plowing into the vacuum pipe wall, even when the gross error should occur. Since the main isotope created in carbon is C^{11}, which has about 20 minutes of half life, the maintenance is a lot easier than isotopes created in stainless steel.

f) The temperature sensitive switch (bimetalic contact) should be placed around collimators and other places around the beam pipe to interrupt the beam when the error occurs.

g) Devise the position of the beam monitoring system which does not require neither electrical penetration or mechanical flange which had been source of the vacuum problem.

h) The optical system must be simple enough so that after initial tuning almost anyone can turn the beam on.

i) The optical elements must be as far away from the BLIP target area to minimize the radiation damage and be easier to maintain.

Since the main radioisotopes produced from aluminum have a half-life of about 15 hours, we used aluminum for the vacuum chamber. All of the optical elements were replaced to dc elements. In order to eliminate electrical penetration, we decided to use radiation monitors around graphite collimators. By minimizing radiation at collimators, we can minimize the number of "halo" protons hitting side walls. The radiation monitor used is aluminum cathode electron multiplier, which has good linearity for a wide range of outputs. Since using secondary electron emission from aluminum cathode inside the tube, the radiation damage to the properties of the monitors should be negligible. The operational results of the electron multipliers are going to be reported elsewhere.

III. Optics

As mentioned above, the purpose of this transport system is to transport 200 MeV protons from the linear accelerator to the BLIP target with minimum loss of the proton and insensitive to the small energy change of the particle. The transport system must have complete momentum recombination. Since the strength of the first kicker magnet is fixed by the availability of the existing magnet and power supply, we used two bends of 7.5° and 22.5° which also is fixed by the existing location and direction of the BLIP facility. A horizontally focusing quadrupole is placed 3/4 way between two benders in order to recombine the momentum. The quadrupole triplet is placed downstream of second bender to focus the beam onto the BLIP targets. The properties of the beam at the exit of the linear accelerator was estimated to

$$\alpha_x = -.964 \qquad \alpha_y = 1.998$$

$$\beta_x = 144.9 \text{ in.} \qquad \beta_y = 258.3 \text{ in.}$$

$$\varepsilon_x = .1625 \text{ in. mr} \qquad \varepsilon_y = .158 \text{ in. mr}$$

and with the aid of a computer to calculate the optics to BLIP target. Fig. 1 shows the floor layout and Fig. 2 shows the envelope of the beam in horizontal and vertical direction. The size of the beam at BLIP target can be controlled by the quadrupole triplet. A profile monitor and current transformer is placed in the vacuum right downstream of the last quadrupole. They are only electrical penetrations for entire vacuum system. Another profile monitor and current transformer is placed downstream of vacuum window inside the helium atmosphere. They are used to tune the beam location and size. The upstream tunings are all relied on the radiation monitors.

IV. Operational Experience

The system was installed in 1976 summer shutdown, and initial operation went very smooth. The radiation level in the area of BLIP tunnel is minimal after a few months of operation. The radiationally hottest place in the entire system is where the profile monitor is at the end of the tunnel. The 100 ~ 150 μ-amperes of beam current operation is routine.

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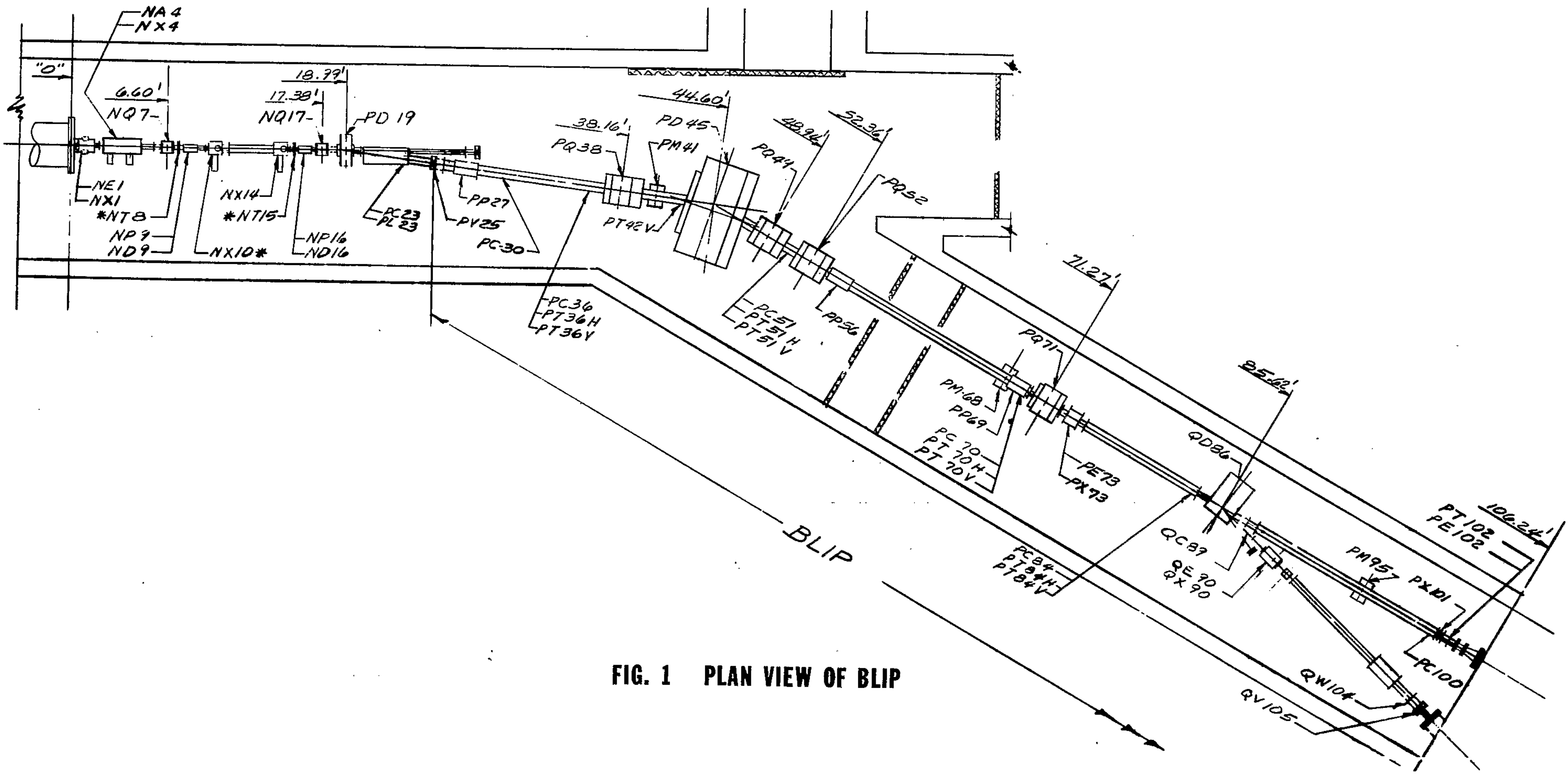

FIG. 1 PLAN VIEW OF BLIP

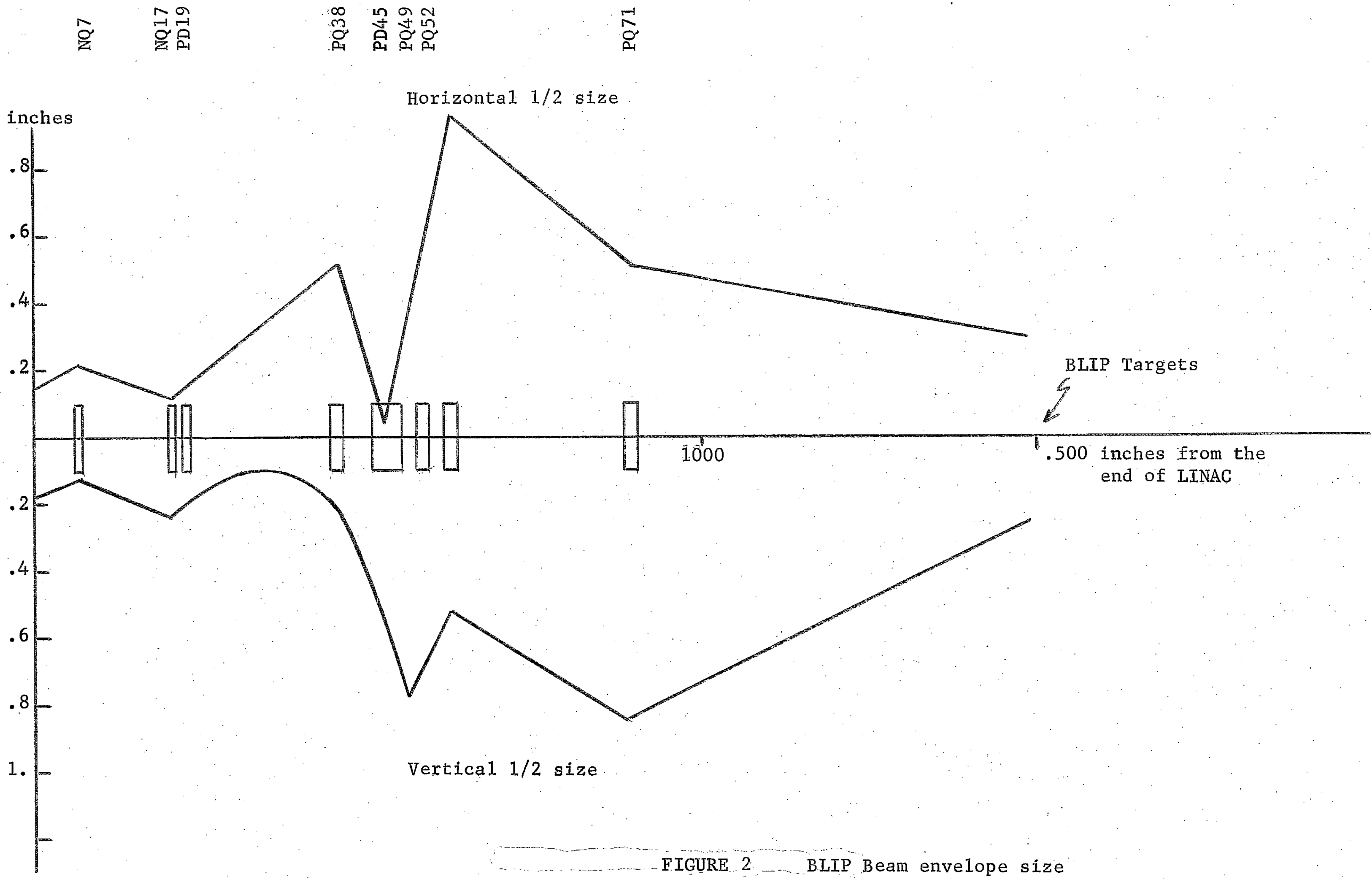

FIGURE 2 BLIP Beam envelope size