C-A Unreviewed Safety Issue (USI) Form

Title of USI: New Booster Dump and New Slow Extraction Components for Booster to BAF

Description of USI (use attachments if necessary):

With regard to the new Booster dump, the dump design, planned losses, induced activity in soil, shielding, cap design and limiting conditions for operations remain unchanged. There are no changes in electrical hazards, fire hazards, radiation hazards or changes to relevant protection systems for the Booster. Only the location of the dump in the Booster Ring is changed and a new cap is installed in the earth shield above it. The dump is moved from D section to B section. See attached.

With regard to major new slow-extraction components, a thin septum magnet, thick septum magnet, stripper foil and collimator are inserted in the space freed up by moving the beam dump from D section. A 13-inch pipe has been inserted through the earth-berm at D section to allow extraction of beam into the BAF tunnel. There are no changes in electrical hazards, fire hazards, radiation hazards or changes to relevant protection systems for the Booster. See attached.

It is noted that the existing Booster earth shield and cap were designed for a planned annual beam loss in the D section of 2.9×10^{19} nucleons at 1.5 GeV (Booster FSAR, page 68) or equivalent (4.3×10^{19} GeV). This planned loss was due to the presence of a dump. As indicated in Appendix 3 of the BAF SAD, 7×10^{16} GeV from high-energy nucleons is the planned annual loss, which is 0.16 % of the design loss for this location in Booster. Thus, the new extraction equipment is adequately shielded for protection against radiation and the area is adequately capped for protection of groundwater.

Title and Date of Relevant SAD: Booster Final Safety Analysis Report, 1991
http://www.rhichome.bnl.gov/AGS/Accel/SND/BoosterSAD/BOOSTER.PDF

Committee Chair or ESHQ Division Head must initial all items. Leave no blanks:

ITEM	APPLIES	DOES NOT APPLY
Decision to not revise the current SAD and/or ASE at this time.	ETL	
The hazard associated with the proposed work or event is covered within an existing SAD and/or ASE.	ETL	
SAD Title and Date: **Booster Final Safety Analysis Report, 1991**	ETL	
This Form and attachments, if necessary, shall be used to document the USI until the next revision of the appropriate SAD.	ETL	
Decision to submit a revised SAD and/or ASE to the BNL ESH Committee.		ETL
The hazard associated with the proposed work is not appropriately included in an SAD.		ETL

Ray Karol — 5-8-01
Signature of C-A Committee Chair or C-A ESHQ Division Head — Date

Edward T Lessard — 5-8-01
Signature of C-A Associate Chair for ESHQ — Date

Specific Changes to the Booster Final Safety Analysis Report

Replace Old Section:

2.4.6 Beam Dump and Catcher

In order to dispose of the beam during studies and aborts, a beam dump system consisting of a dump kicker and an absorber block is provided as shown in Figure 12.7. The beam dump is a 1 m long steel cylinder surrounding the beam pipe. It has a radial thickness of 19 cm. It is shielded by an additional 20 cm of iron in order to reduce the activation of nearby soil outside the tunnel enclosure. A movable lead curtain slides from an area where activation is slight to form a wall around the dump in order to eliminate personnel exposure from the residual radiation residual radiation. The Incoloy steel cylinder has a 2.54 cm lip interior to the vacuum chamber which is, by design, the limiting aperture: for the Booster, and thus serves to catch the beam losses during injection and acceleration.

With New Section:

2.4.6 Beam Dump and Catcher

In order to dispose of the beam during studies and aborts, a beam dump system consisting of a dump kicker and an absorber block is provided. The location of the beam dump is in the B section and is shown in the attached Figures 1 and 2. The beam dump is a 1 m long steel cylinder surrounding the beam pipe. It has a radial thickness of 19 cm. It is shielded by an additional 20 cm of iron in order to reduce the activation of nearby soil outside the tunnel enclosure. Time, distance and shielding are used during maintenance periods in order to reduce personnel exposure from residual radiation from the dump. The Incoloy steel cylinder has a 2.54 cm lip interior to the vacuum chamber that is, by design, the limiting aperture: for the Booster, and thus serves to catch the beam losses during injection and acceleration.

An impermeable cap to prevent rainwater from entering activated soil near the beam dump has been installed above the dump kicker in B section. The cap is similar in design to the existing cap used for the dump formerly positioned at the D section. The cap at the D section remains in place undisturbed and is overlapped by the cap for the BAF tunnel.

Add Section:

2.4.4.1 Slow Extraction at the Booster

The Booster has operated since 1991 as an injector of protons and heavy ions into the AGS. In order to deliver an external slow extracted beam to the Booster Applications Facility, new equipment was added that rearranges existing apparatus.

A thin septum magnet is installed in the D section and is similar in design and in specification to the F5 extraction septum that is used in the AGS but is built to 10^{-11} Torr UHV vacuum standards. A thin 0.76 mm copper septum is used to minimize beam loss. Inconel water lines are brazed to each edge of the septum to cool it.

A thick septum magnet is installed in the D section and is similar in concept to the present F6 extraction septum magnet used for the Booster. The magnet core and the water-cooled copper bus work are located outside of the vacuum. A special "Y" chamber is used with an Inconel chamber for the extracted beam, which fits in the aperture of the magnet. The Booster circulating beam goes in a nickel-plated steel chamber that is welded to the Inconel chamber at the upstream end. This magnet is built with four small conductor windings in the septum and the backleg. This design is also used in the AGS F10 extraction septum magnet that operates DC with similar currents.

A stripping foil mechanism and a radial single-jaw collimator are upstream of the thick septum magnet. This foil holder/changer is similar in design to the mechanism currently used for Booster H^- injection.

Power supplies for these components are located in Building 930 upper equipment bay (UEB) and the first floor. Building 930 is a power supply building that was described in the Booster Final Safety Analysis Report. Power distribution remains the same. See attached Figures 3 and 4.

USI: New Booster Dump and New Slow Extraction Components for Booster to BAF

Figure 1 3 D View of Booster Showing BAF Tunnel, BAF Extraction and Booster Dump

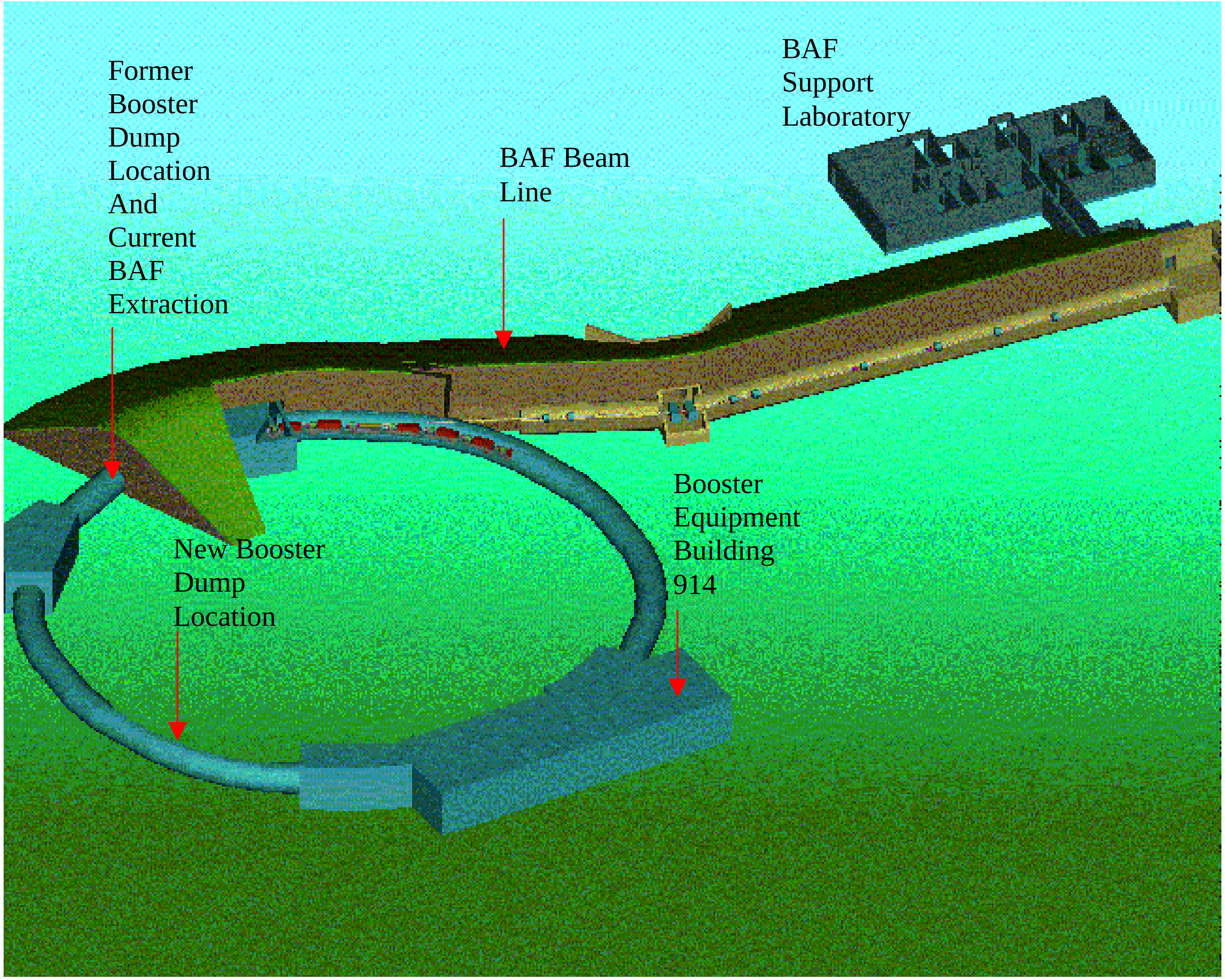


Figure 2 Booster Slow Extraction in D Section and Booster Dump in B Section

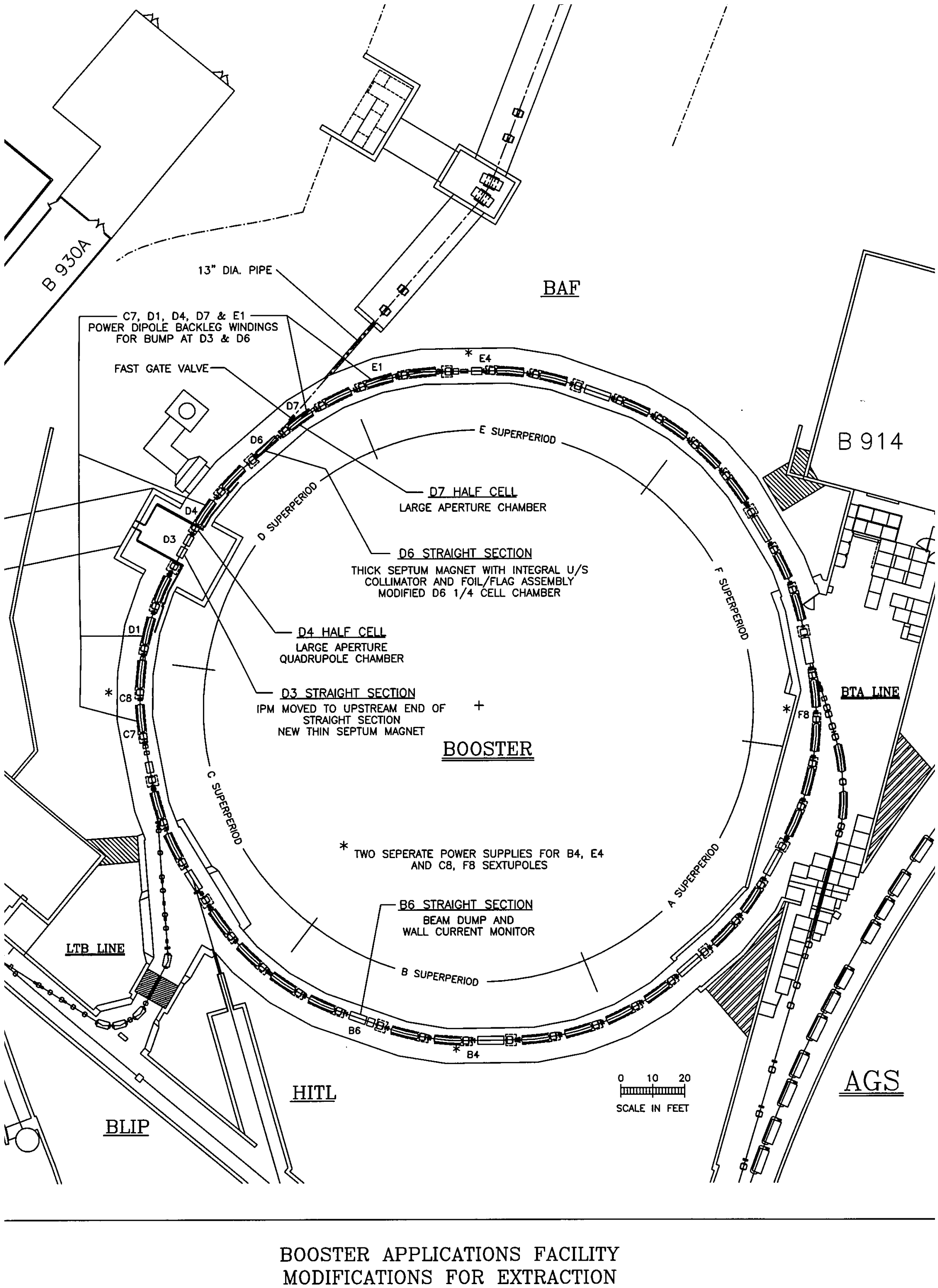
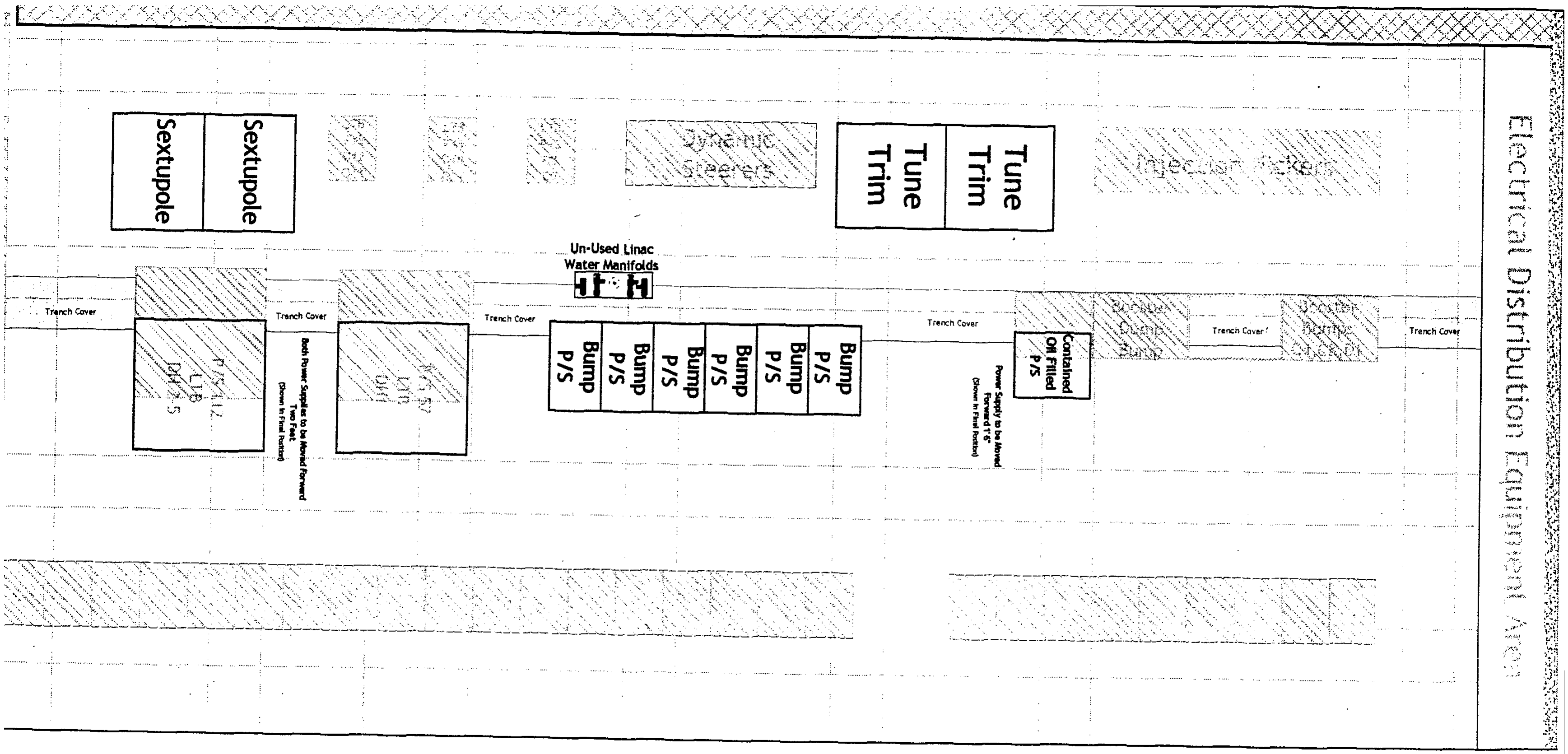
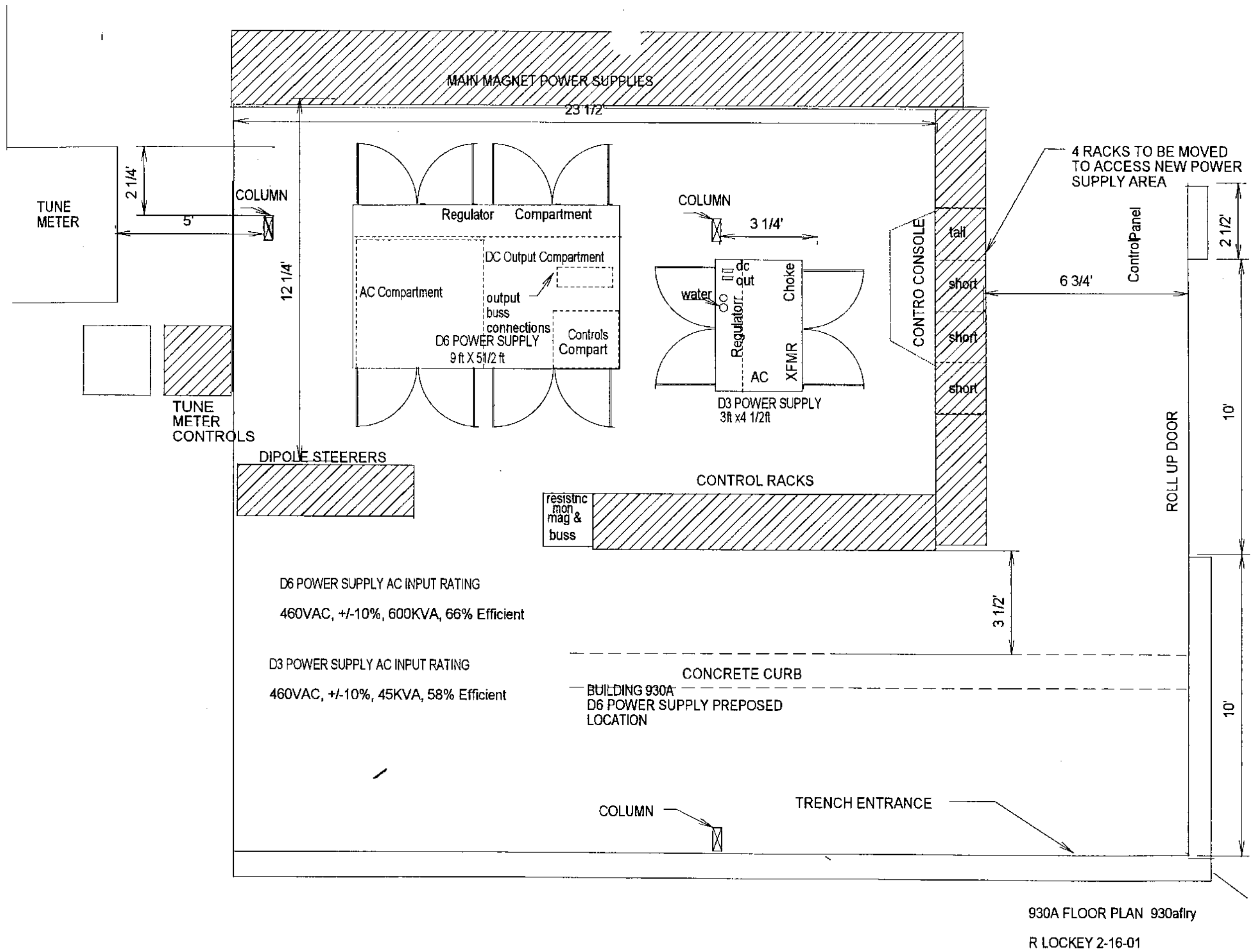


Figure 3 Location of Power Supplies for Slow Extracted Beam Components in Booster



BAF Equipment Locations in Building 930 UEB

Figure 4 Location of D3 and D6 Power Supplies for Slow Extracted Beam Components in Booster



Requirements for a Cap Over the Booster Beam Dump

I. Description of the Problem – Design Criteria

A new beam dump will be installed in the Booster in the B6 straight section. This dump is intended to be a position of large beam loss when the high-intensity HEP program (MECO and KOPIO) runs during RHIC stores. A cap (or liner) must exist over the soil in the vicinity of this beam dump to prevent the leaching of relatively high concentrations of radionuclides (^{3}H and ^{22}Na) from the soil into the water table. This note describes the design of the dimensions of the cap.

A recently adopted criteria[1] limits the concentrations at the water table immediately beneath the loss point to extremely small values: 5% of the drinking water limits for either ^{3}H or ^{22}Na. This corresponds to 20 pCi/l of ^{22}Na or 1000 pCi/l of ^{3}H. Ref. [1] also describes a model whereby the drinking water limits result from the leaching of a soil concentration of 2.1×10^{7} ^{22}Na atoms/cc-year or 3.7×10^{8} ^{3}H atoms/cc-year. The limits for leachable soil concentration then become 1.05×10^{6} ^{22}Na atoms/cc-year and 1.85×10^{7} ^{3}H atoms/cc-year.

In the past, the CASIM Monte Carlo program has often been used to evaluate the concentrations of the two radionuclides of concern. In part this was because measurements both at FNAL and BNL[2] had established a production rate of 0.02 ^{22}Na atoms per calculated CASIM interaction in soil and 0.075 ^{3}H atoms per calculated interaction *at the position of the maximum density of interactions*. However, comparison of CASIM with other codes[3] has shown that CASIM drastically underestimates the interaction density in the backwards direction. In part for that reason the codes MCNPX[4,5] and N-SHIELD[3] are used in this evaluation. The only weakness of MCNPX known to this author is that statistical precision can become a problem in "deep penetration" calculations. N-SHIELD is used because it is better when statistics require extrapolations (as in this case), but the results of both codes will always be shown, and N-SHIELD results will be "corrected" by the MCNPX results.

The CASIM production rates will be used with the N-SHIELD (say) fluences above 20 MeV. This is somewhat *conservative*, since the CASIM threshold is 47 MeV. For ^{22}Na (the most restrictive of the two isotopes) annual concentration in soil is given by:

$$Eqn(1) \qquad N_P \times \frac{\phi(x,y,z)}{\lambda} \times 0.02$$

where N_P is the number of protons on the dump, $\phi\ (x,y,z)$ is the hadron fluence > 20 MeV per proton at the point (x,y,z) in the soil, λ is the (high energy) interaction length, and, as mentioned above, there are 0.02 ^{22}Na atoms created per spallation reaction in soil.

$\phi\ (x,y,z)$ is the quantity that will be evaluated with the Monte Carlo programs. N_P is obtained from an evaluation by the Liaison Physicist of Booster losses during g-2 running.[6] The loss was 4.3×10^{16} geV-nucleons per hour. I have assumed annual running of 38 weeks at 75%

efficiency. The result of 4788 hours per year gives 2.06×10^{20} GeV-nucleons per year or 1.03×10^{20} 2 GeV protons per year. The value of λ is taken as 50.2 cm in BNL soil.[7] Setting Eqn (1) to the criteria of 1.05×10^6 ^{22}Na per cc per year gives the limiting condition for the fluence > 20 MeV:

$$\phi(x,y,z) \leq 2.55\times10^{-11}\ hadrons/cm^2 - p$$

The task of the calculation is to determine the boundary where this condition is true.

II. Transverse Geometry Estimate

The dump sits asymmetrically in the Booster tunnel, with a distance of closest approach to the tunnel wall of about 102 cm. A two-dimensional simulation was performed with a cylindrical approximation of the dump[8] within a circular 102 cm. radius tunnel. In the first set of simulations the maximum flux in the beam direction was calculated as a function of depth in soil with both codes.

The results are shown in Fig. 1. N-SHIELD underestimates the fluence in the beginning of the soil, but the agreement is very good after about a meter depth. The line shown on Fig. 1 is:

$$R^2 \times Fluence = 1.22\times10^{-5} \times \exp(-d/61)$$

where R (in m) is the distance from the beam line and d (in cm) is the depth in soil. **R = 6.7m (22 ft.) is required to obtain the fluence value in the preceding section**. Measured from the tunnel center line, the distance is 24 ft. in the direction toward ring center and 23.5 ft. in the opposite direction. Note that this implies that a cap on the top of the berm is required unless the berm thickness is greater than 18.5 ft. in which case the cap may be buried in overlying earth shielding. A liner after, say, 12 ft. of earth simply would not suffice since the earth on top of the liner would still have too great a radionuclide concentration.

III. Longitudinal Geometry Estimate

Fig. 2 shows an actual layout of the beam dump as it will exist in the Booster tunnel. As shown, a line along the beam line encounters the wall 13.6m from the beginning of the dump. To estimate fluences in the forward and backward directions, the very simple simulated geometry shown in Fig. 3 was adopted. As shown, a solid soil wall was placed at the projected positions of the beam line with the tunnel wall in both the forward and backward directions. The 102 cm. radius tunnel was retained, and material approximating two Booster magnets was included (although the magnetic field was not).

Figs. 4 and 5 show the results of both codes in the forward and backward end walls.[9] The line shown in Fig. 3 through the N-SHIELD values has been multiplied by 2 to "correct" these results to those obtained by MCNPX.

In the backward direction, statistics are very difficult. Beyond the point in Fig. 5 corresponding to a depth of 110 cm., MCNPX gave zeros for very long computer runs. The line shown through the N-SHIELD points was, as in the case of the forward direction, multiplied by 2.

Similar to the expression in the transverse direction, the expressions used for obtaining the end wall fluences are the following:

$$Forward\ \ Direction:\ \ Z^2 \times Fluence = 2.60 \times 10^{-4} \times \exp(-d/69)$$

$$Backward\ \ Direction:\ \ Z^2 \times Fluence = 3.54 \times 10^{-6} \times \exp(-d/55.5)$$

where the units are as noted above: Z in m and d in cm.

Application of these expressions to the actual geometry in Fig. 2 along the beam line (with an appropriate correction for the concrete walls in the forward direction) gives the Z values at which the fluence falls below the criteria. The final result, shown with the transverse dimension found above, is shown in Fig. 6. Measured from the beam line at the beginning of the dump, the area of concern is 22 ft. in the ring center direction, 25.5 ft. in the direction opposite ring center, 80 ft. in the forward direction along the beam line, and 54.5 ft. in the backward direction along the beam line. If necessary, the transverse extent could be reduced somewhat as the distance from the dump increases. An actual cap must be somewhat larger, as Ref. [1] also mandates that a 10° angle be allowed for horizontal sub-surface water flow.

References/Footnotes

1. Design Practice Specification for Know Beam-Loss Locations (http://www.rhichome.bnl.gov/AGS/Accel/SND/EMS/BeamLoss.pdf)

2. P.J. Gollon et. al., "Production of Radioactivity in Local Soil at AGS Fast Neutrino Beam," BNL-43558

3. A.J. Stevens, (Penny working on this.)

4. L. S. Waters, Ed., "MCNPX USER'S MANUAL," LANL Report TPO-E83-UG-X-0001, (1999). See also H.G. Hughes, R.E. Prael, R.C. Little, "MCNPX – The LAHET/MCNP Code Merger," X-Division Research Note, 4/22/97. The version number of the code used in this note is 2.1.5.

5. The physics modeling of MCNPX is very good in the few GeV region, which is another reason for not using CASIM. The maximum fluence densities in a transverse geometry of all three programs are in reasonably good agreement, but the position of that maximum varies.

6. C. Gardner, private communication.

7. This is the N-SHIELD value. BNL soil is defined as the following atomic composition at a density of 1.9 g/cc.: .087H, .6231O, .2899Si.

8. Drawings of the dump were provided by J. Hock. An exception to the cylindrical approximation was the rectangular dump aperture. The beam was incident 7mm. from this aperture on the upstream face of the dump.

9. The errors shown in all calculations are the estimate of the standard deviation from four runs with different random number seeds.

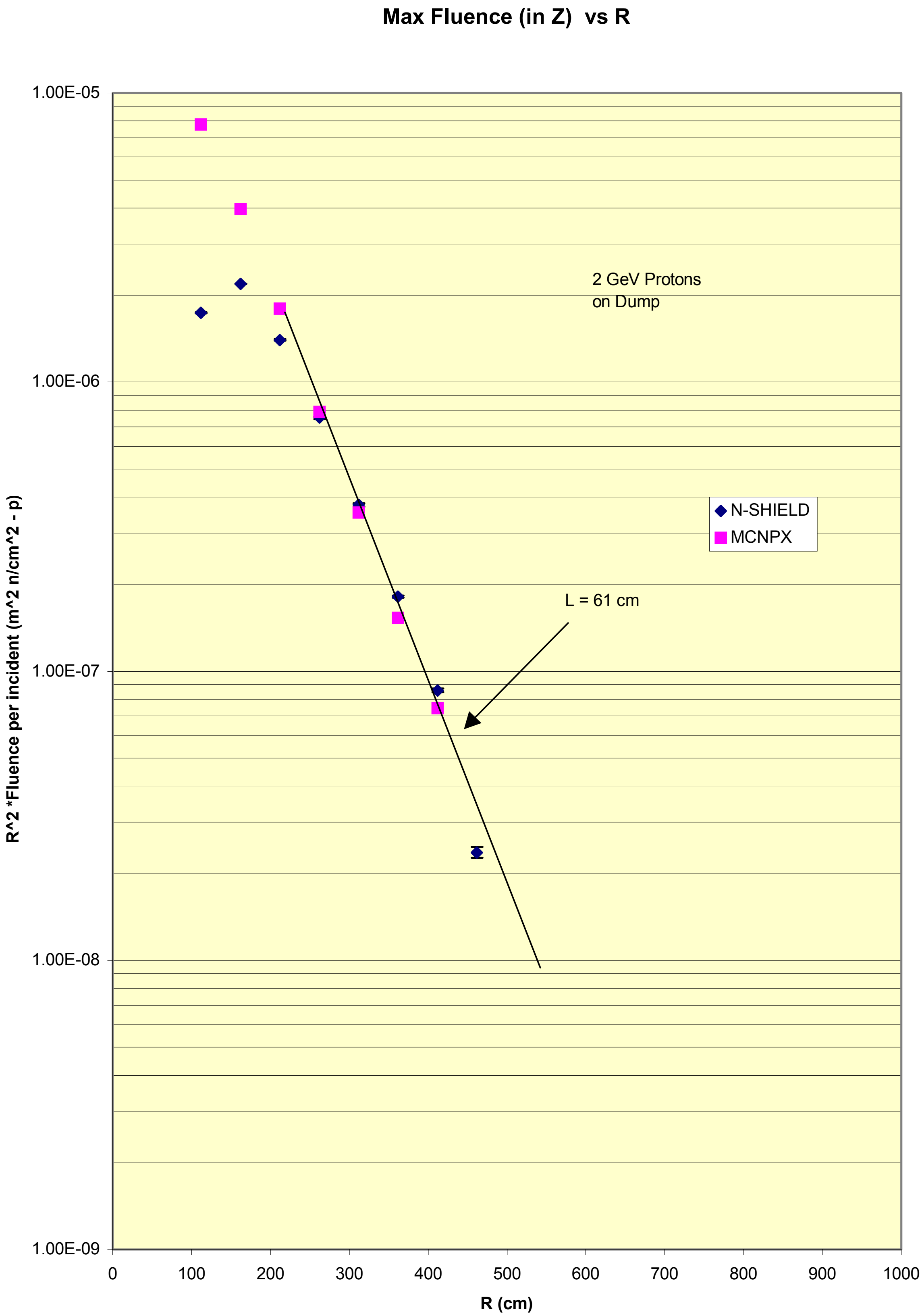

Max Fluence (in Z) vs R
2 GeV Protons
on Dump
N-SHIELD
MCNPX
L = 61 cm
R^2 *Fluence per incident (m^2 n/cm^2 - p)
R (cm)
1.00E-05
1.00E-06
1.00E-07
1.00E-08
1.00E-09
0
100
200
300
400
500
600
700
800
900
1000

Fig. 1

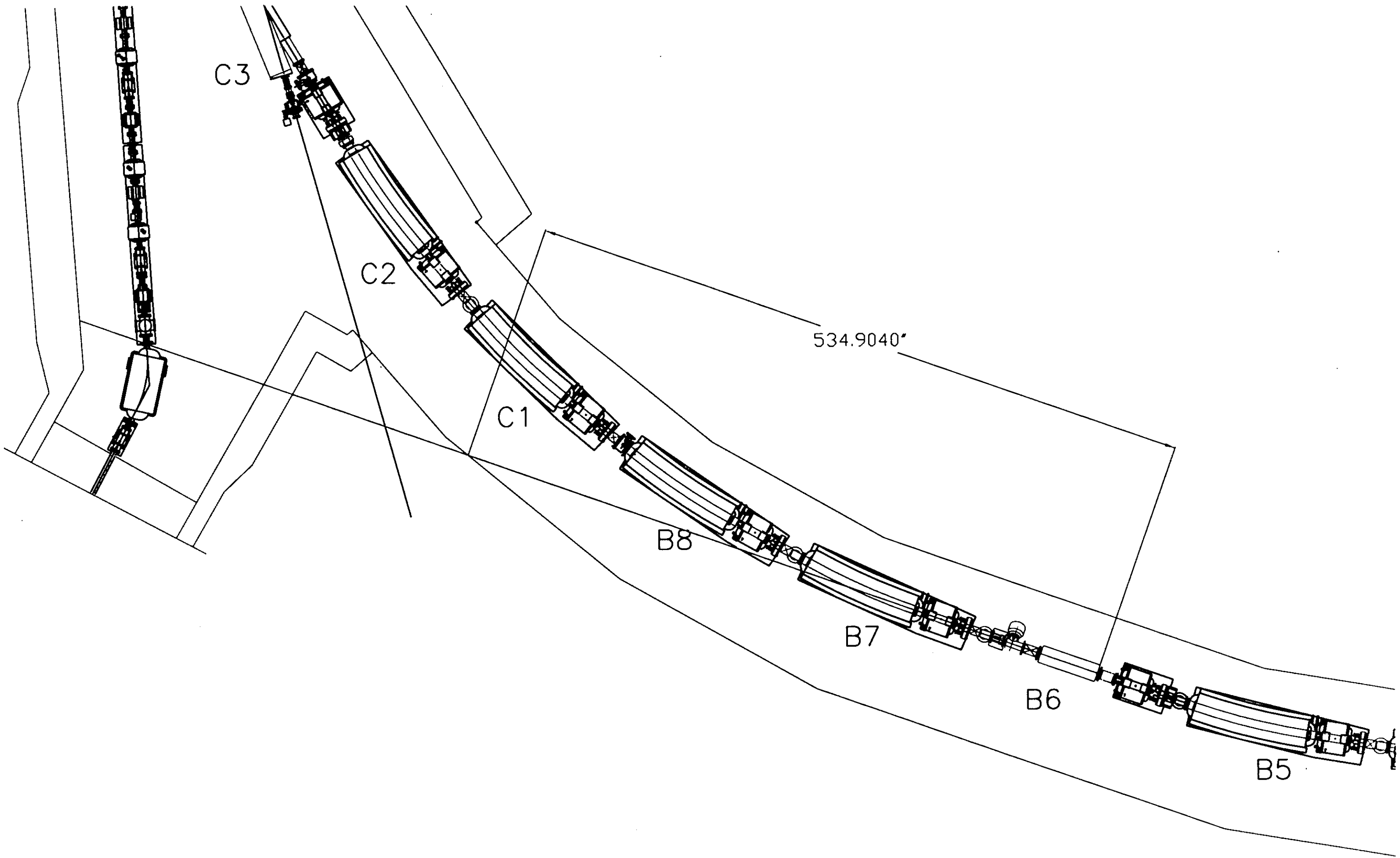


Fig. 2

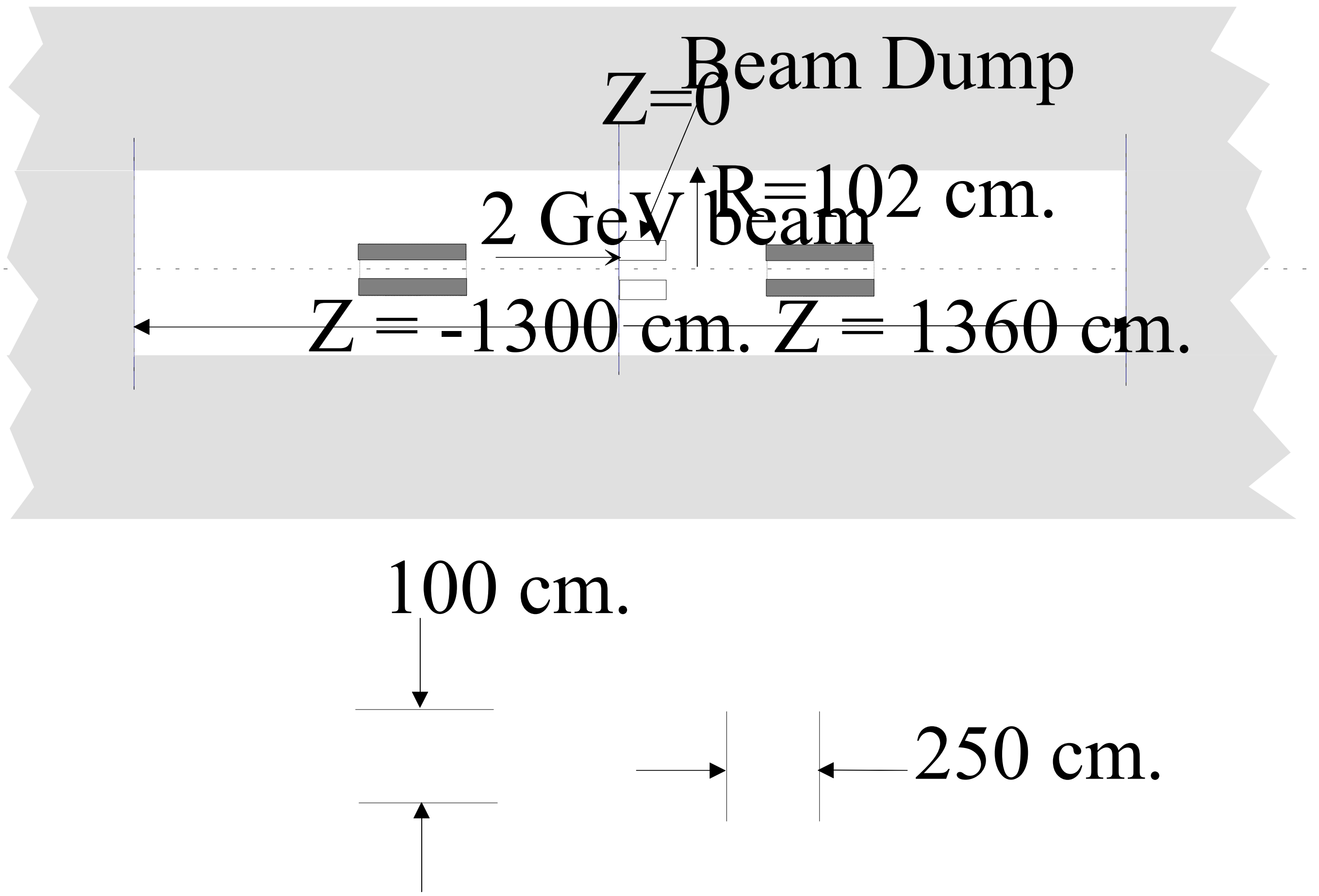


Fig. 3

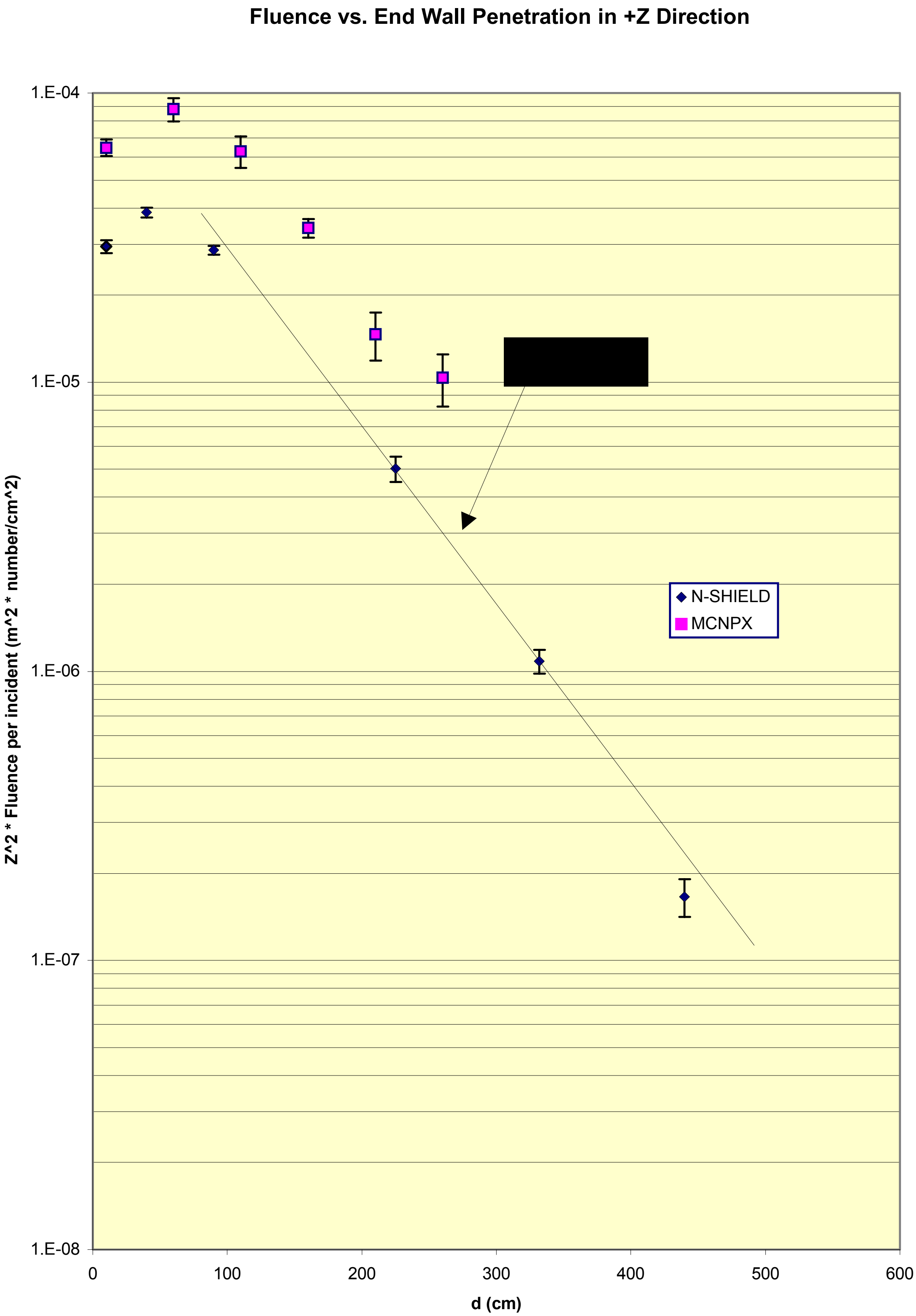
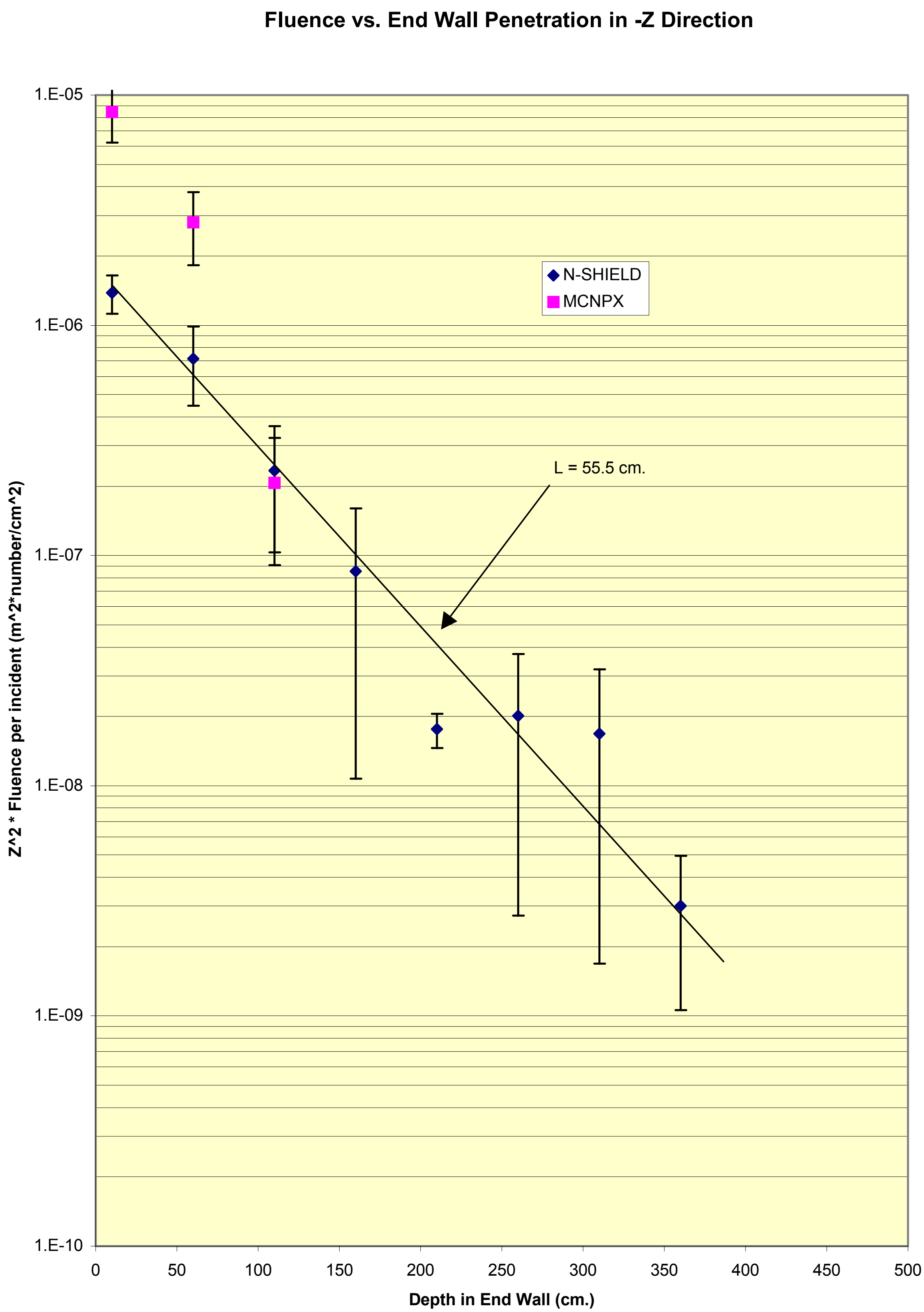

Fluence vs. End Wall Penetration in +Z Direction
1.E-04
1.E-05
1.E-06
1.E-07
1.E-08
Z^2 * Fluence per incident (m^2 * number/cm^2)
0
100
200
300
400
500
600
d (cm)
[redacted]
N-SHIELD
MCNPX

Fig. 4



Fluence vs. End Wall Penetration in -Z Direction
Z^2 * Fluence per incident (m^2*number/cm^2)
1.E-05
1.E-06
1.E-07
1.E-08
1.E-09
1.E-10
0
50
100
150
200
250
300
350
400
450
500
Depth in End Wall (cm.)
N-SHIELD
MCNPX
L = 55.5 cm.

Fig. 5

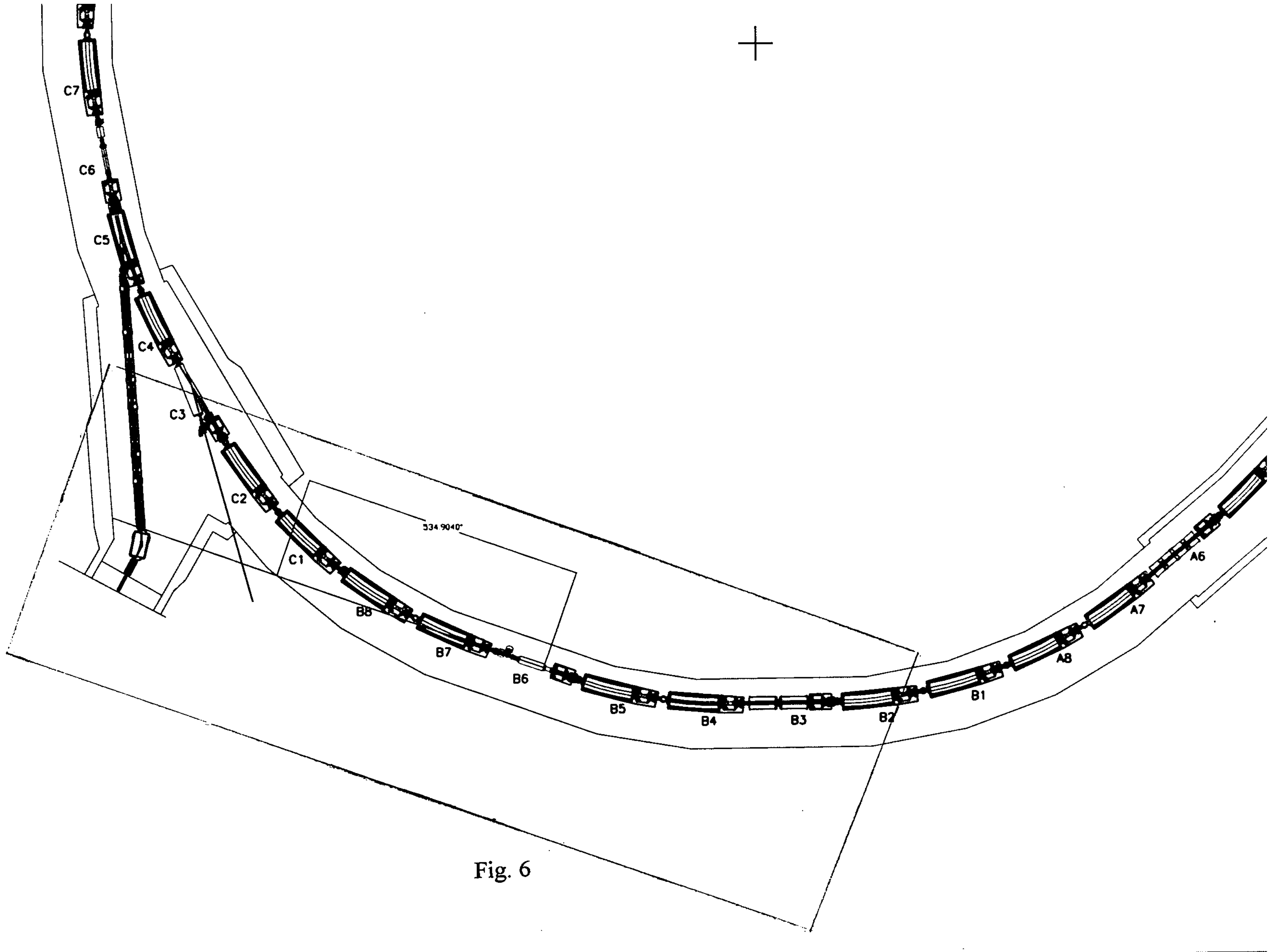


Fig. 6

RSC Sub-committee Meeting, 12/11/01

New Booster Dump at B6 – Concerns are Soil Activation and Skyshine

(1) Source Assumed

From Kip Gardner– 4.3×10^{16} GeV-nucleons/hr.
38 weeks/year at 75% Efficiency

(2) Sky Shine

"Absolute" Estimate using MCNPX.

(a) Use Approximate Berm contour, but only 7 ft. depth
(b) Scale to 10 ft. depth and compare with calculation at this depth

Note. At 10 ft. depth, agrees within a factor of 3 with CASIM + Distenfeld & Colvett skyshine formula!!

(c) Scale to 18 ft. Result is 52 mrem/yr at 90 ft. distance. This is Bldg 931 (BLIP). With 1/8 occupancy factor, get 6.5 mrem/yr. At 225 ft. (entrance of 914) about 8 mrem/yr.

(3) Soil Activation

(a) Use MCNPX and N-SHIELD (N-SHIELD used only for extrapolations – always normalized to MCNPX)

(b) Criteria is an annual density of ^{22}Na atoms which, in the context of the Lessard model, would give 5% of drinking water standard at the water table.

(c) Lots of approximations (including .02 ^{22}Na 'per star'). Result is cap design on next page.

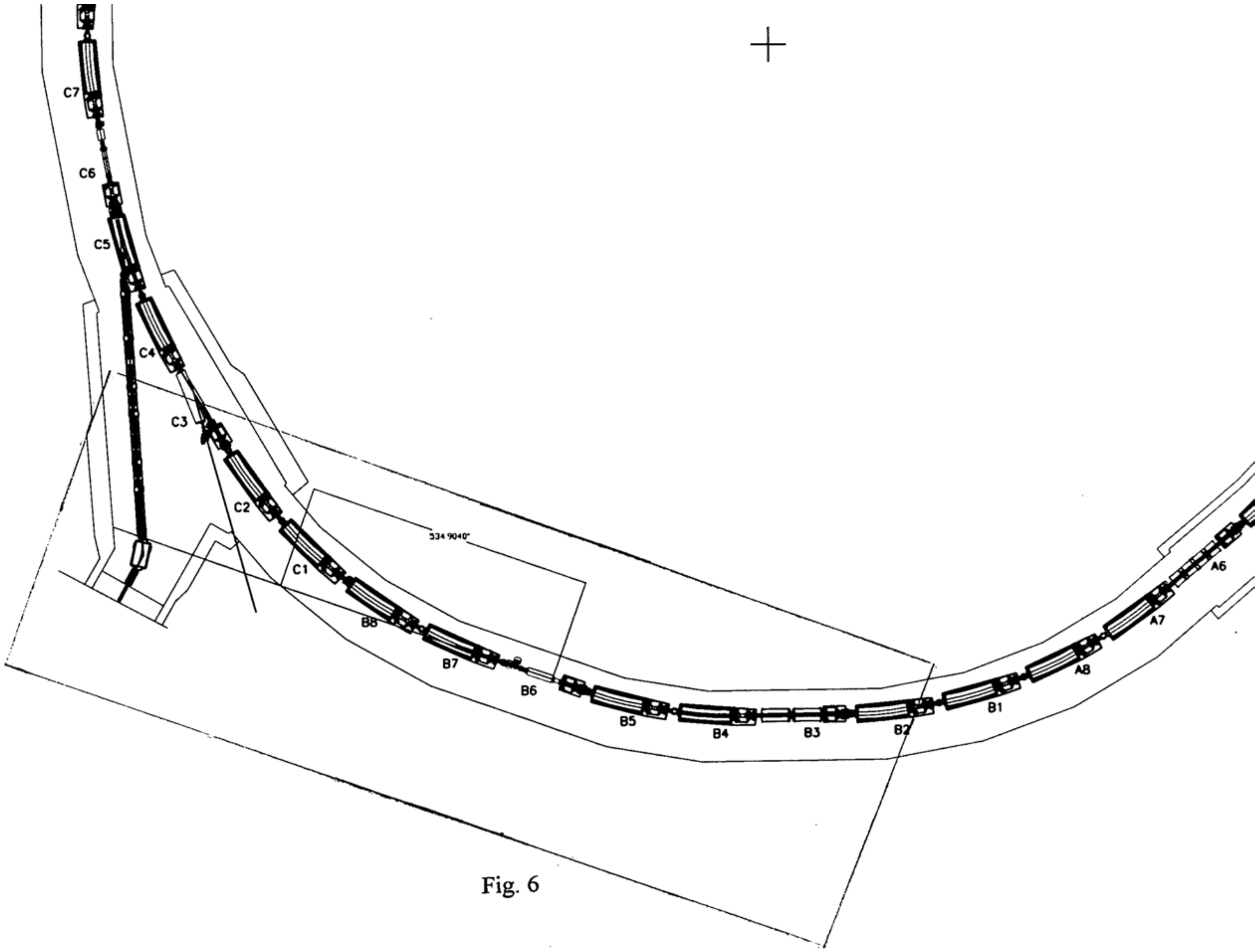


Fig. 6