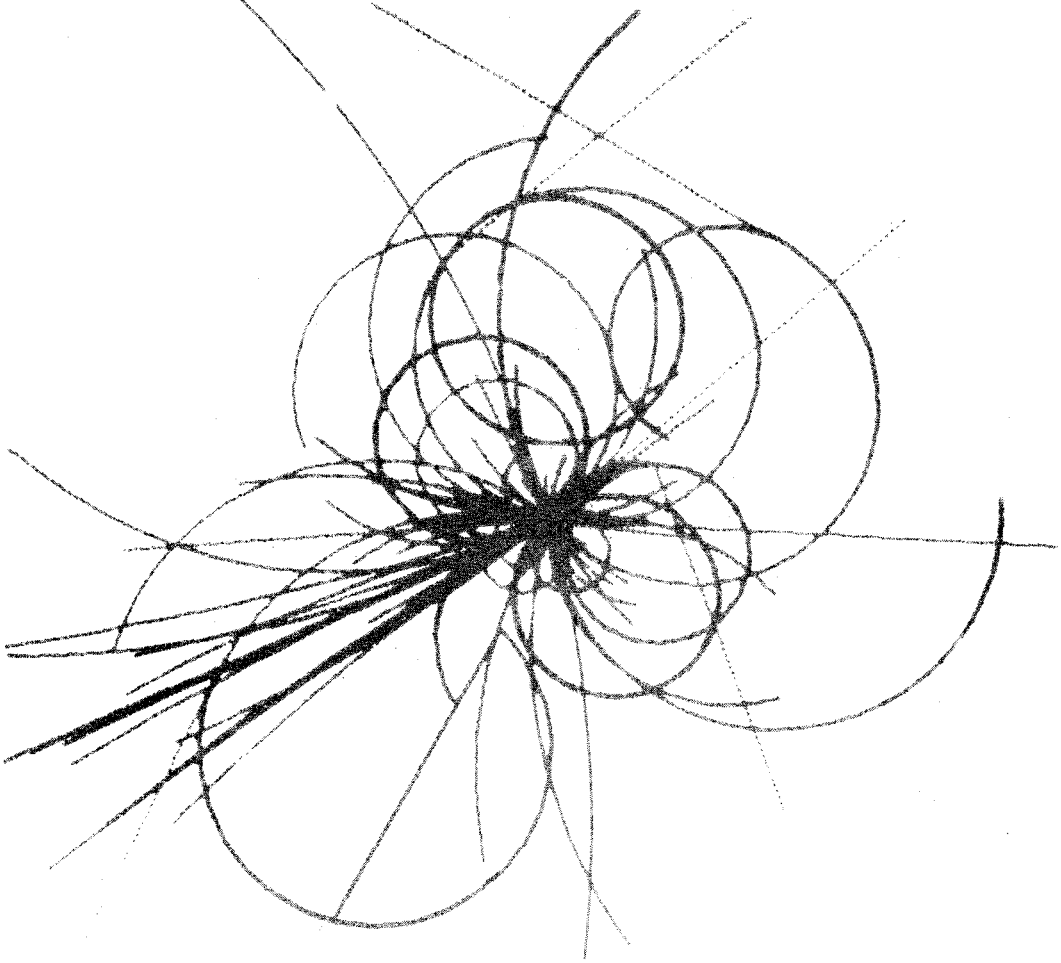
SSC-SR-1016

The Superconducting Super Collider



SSC Workshop on Environmental Radiation
14–18 October 1985

SSC Central Design Group
Lawrence Berkeley Laboratory
Berkeley, CA 94720

9 January 1986

ERRATUM SSC-SR-1016

Page 4, first paragraph,

line 19 reads: full intensity (1.3×10^{13} protons)

should read: full intensity (1.3×10^{14} protons)

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"Tous ce qui est simple est faux,
Tous qui n'est pas est inutile."
P.Valery

*Operated by Universities Research Association for the U.S. Department of Energy

WORKSHOP ON ENVIRONMENTAL RADIATION

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I. Workshop Agenda

II. Computer Codes for Accelerator Radiation Calculations

III. Radiation Considerations for Accelerator Ring Separations

I. INTRODUCTION

The Superconducting Super Collider is a 20 TeV-on-20 TeV proton beam collider where two 20-TeV proton accelerators whose beams, rotating in opposite senses, are brought into collision to provide 40 TeV in the center of mass. The scale of the project is set by the 6.6 tesla magnet guide field for the protons which results in a roughly circular machine with a circumference of 83 km (51.5 mi.). The energy scale of the proton beams and the physical scale of the machine are an order of magnitude greater than for any presently operating or contemplated proton accelerator yet the facility must be operated within the same strict radiological guidelines as existing accelerators in the U.S. and Europe.

To ensure that the facility conforms to existing and projected guidelines both in design and operation, the Workshop was charged to review the experience and practices of existing accelerator laboratories, to determine the relevant present and projected regulatory requirements, to review particle production and shielding data from accelerators and cosmic rays, to study the design and operational specifications of the Collider, to examine the parameters set forth in the Siting Parameters Document, and to evaluate the computational tools available to model the radiation patterns arising under various operational and failure scenarios.

In light of the preceding, the Workshop was asked to:

- define the factors and conditions that must be taken into consideration in the design and operation of the SSC facilities,
- describe, on the basis of the SSC design as presented, possible operational scenarios which might produce environmental radiation effects,
- determine what relevant information exists in the literature and in the collective experience of the participants,
- determine what additional information would be required from experiments or calculations to provide an adequate radiation design for the SSC.

This report summarizes the extensive and intensive presentations and discussions of the Workshop. A great deal of material, much of it in the form of internal reports from the various laboratories and drafts of works in preparation, was provided by the participants for the various topics. This material, including the viewgraphs used by the presenters, forms the background and basis for the conclusions of the Workshop and, as such, is an important part of the Workshop. An introduction to the material and a catalog by topic are presented as section 6 of this report.

2. SOURCES, LEVELS, AND NATURE OF RADIATION AT THE SSC FACILITY

The primary source of radiation at the SSC facility is the interaction of the beams with one another or with components of the accelerator. The magnitude of the resulting radiation is, in general, directly proportional to the number of beam protons involved in a given interaction. The Workshop focussed on three classes of interactions, normal beam interactions and routine beam disposal, the accidental loss of a full beam of protons at a point in the accelerator, and routine operational losses.

a. Normal beam interactions and routine beam disposal.

At the end of a Collider cycle the beam remaining in the machine will be disposed of by steering it into an abort dump. This is the most severe radiation problem associated with the SSC. These dumps, one for each beam, must be designed to absorb the thermal and mechanical shock of the approximately 400 MJ of a full energy, full intensity stored beam at the maximum design repetition rate. The dumps must incorporate sufficient shielding to protect the surrounding environment and nearby accessible areas from radiation produced when the beam energy is absorbed.

The radiological effects outside of the shielding in the vicinity of the abort will depend on whether the beam interacts directly with the dump, or with scattering foils or similar devices placed upstream of the dump to diffuse the beam over its face. Two components of the radiation from the beam striking the dump must be considered --the hadron component, which is of most concern for ground water and residual radioactivation of components, and the muon component, which may have a range of up to 4-5 kilometers downstream of the dump in a soil shield.

The hadron component is intense, but relatively short-ranged. The structure and size of the dump must be such as to minimize the environmental impact due to radioactivation of any ground water outside the dump enclosure. A further requirement is that the dump must be sufficiently shielded to allow necessary maintenance operations in its vicinity. An example of such a dump exists at the Tevatron, consisting of a carbon-plate core in a water-cooled aluminum box, surrounded by a massive steel enclosure. This is sealed in concrete which is waterproofed to exclude groundwater from the activated region. There is sufficient depth of soil above the dump that no radiation is detectable at the ground surface for a full-energy, full-intensity beam abort.

As noted, the muon component, which is projected forward in the direction of the beam, is very long-ranged, up to 4-5 kilometers from the dump. Because of this long range, the topography in the vicinity must be carefully studied in placement of the dumps. For a near-surface site it is preferable that the aborted beam be pitched downwards to ensure that the muon component is also pitched downwards, and thus does not broach the surface before it is attenuated to permissible levels. This area downstream of the dump presents a potential radiation hazard and must be monitored and under the control of the laboratory.

The second normal loss situation considered was the beam interactions at the six collision points. In a normal collider cycle up to 20% of the stored beams will be lost at the collision points over the course of a store, approximately 20 hours. Here, since two beams are involved, the muon component to be shielded extends in both directions from the interaction region. The presence of the massive detectors will greatly modify the radiation patterns from these interactions; however, since the detectors will not necessarily be in place when the facility is operating, these collision halls should be shielded to achieve permissible radiation levels independently of the detectors. A further consideration for the shielding in this region would be the pitching of the two beams to bring them into collision. For a near-surface facility the forward cone of muon radiation from an upward-pitching beam will either have to be well shielded or dispersed by magnetic fields, or not accessible to the general public. If it were feasible to bring the beams into collision in the horizontal plane, the nominal earth shielding would be adequate.

b. Accidental loss of a full beam at a point.

Like the electron beam used in electron beam welding, a high intensity proton beam is able to burn through metal. For this reason an important element of high energy proton accelerators is the abort system, a multiply redundant system of detectors and beam handling devices to extract the beam from the accelerator in the event of a potential beam loss. The aborted beam is directed to the abort dump described in the previous section. As a result, e.g., in the thirteen years of operation of the synchrotrons at the Fermi National Accelerator Laboratory there has not been any instance of catastrophic loss of the beam in the accelerator during normal operations. It is still possible, however, to hypothesize such a loss in which the entire beam of protons would accidentally interact at a point, and thus deposit the stored energy in a small region in the collider. It was recommended by the Workshop that such hypothetical total beam losses should be considered in the design of the facilities and shielding for the SSC. Because the structure of the magnet lattice is quite different in the arcs (long curved tunnel sections) and the clusters containing the utility and interaction regions separate assessments should be made of the consequences of such catastrophic losses in each case. It was recommended that in all cases the evaluations should be made on the basis of a full energy (20 TeV), full intensity (1.3×10^{13} protons) beam. Only loss of a single beam need be considered since even if both beams were lost by interaction with the same obstruction, the radiological consequences would occur in separate locations along the direction of the trajectories of the parent beams.

In evaluating the radiological consequences of such a loss it is necessary to consider both the prompt radiation due to hadrons and muons, and the residual radioactivity produced in the zone surrounding the tunnel. Since, by hypothesis, the loss is unpredictable, it must be assumed to occur anywhere on the circumference of the accelerator. The effective radiation from the hadron component, which also determines the residual radioactivity, will propagate radially from the interaction points producing a pattern that is symmetric around the accelerator tunnel. The muons, on the other hand, propagate in the forward direction from the interaction point. Taken with the curvature of the ring, this will result in a radiation pattern projected to the outside of the ring.

c. Routine operational losses.

Between normal operations and catastrophic losses there is a class of losses which may be anticipated to occur during routine operations. These might be abnormal losses severe enough to cause a quench of the superconducting magnets, but not severe enough to shut down the machine. This might be, for instance, a mistuned injection kicker. Each such loss might result in less environmental dose than that predicted by the catastrophic loss case treated above, which is, by hypothesis, a once-per-year event; however, because of the potential frequency of occurrence, the total annual dose from these routine operational losses could be higher than that calculated for the catastrophic loss case. The importance of this class of losses on environmental radiation levels can only be addressed by the SSC design team when quench levels and damage levels in the superconducting magnets are understood.

3. COMPUTER MODELING OF ACCELERATOR-RELATED RADIATION

Three separate energy regimes are relevant for computer modeling of accelerator-related radiation and shielding at the SSC: the 1 TeV proton beam from the High Energy Booster (HEB), the 20 TeV proton beam in either of the Collider rings, and the 40 TeV produced in the collision of the two 20 TeV beams.

The calculations for the 1 TeV regime for both the hadron cascade and muon production and stopping are well understood. The calculational models have been checked against experimental data up to the 800 GeV energy of the Tevatron. The models have been used successfully to predict the loss patterns in the Tevatron and subsequently to design beam scrapers to absorb the radiation, thus allowing higher intensity operation.

Calculations involving the interaction of the 20 TeV proton beam with fixed machine elements are especially relevant for protection of machine components, for designing the abort and its associated shielding, and for the shielding around the Collider ring tunnel. The 20 TeV proton beams in the Collider rings are an order of magnitude higher in energy than any existing accelerator-produced proton beam; however, the energies involved in the interactions of these protons with fixed machine elements are bracketed by data

from the ISR and the SPS collider where two beams collide head on with resulting energy equivalent to striking stationary targets at approximately 2 TeV and 150 TeV respectively. Nuclear effects, which are not present in the collider data, complicate the 20 TeV calculations. From comparison with these data, calculation of the hadron production by the 20 TeV beam are reasonably certain. There do remain residual uncertainties in the subsequent cascade calculations.

The muon calculations from the 20 TeV interactions are less certain. A major factor is the uncertainty in the rate of prompt muon production. The highest energy data available from the ISR are ambiguous, and there have been no charm production cross section measurements from the SPS collider. Two source assumptions are suggested: (a) The ratio of prompt muons to pions may be assumed to rise by a factor of three from its measured value at 400 GeV to 0.03% at 20 TeV for all secondary momenta. (b) The cross section for D production may increase to 1 mb, as suggested by some ISR data, with a plausible forward-peaked momentum dependence. The production of prompt muons by energetic secondary pions within the cascade is even less certain, and might be important. This topic clearly merits further careful attention.

Calculations involving the 40 TeV available in the collision of the two 20 TeV beams are important for the shielding around the collision halls and the adjacent beam tunnels. Hadron production distributions are available from existing calculational programs. Existing cascade programs appear to be satisfactory for calculating the radiation transport in the forward direction from the collisions; however, near 90 degrees it is important to include contributions from jet production at large transverse momentum. This has not yet been done. There are good particle and jet-production programs which have been developed for modeling and analyzing collider experiments. It would be useful to incorporate these into the cascade and shielding calculations to improve the data near 90 degrees which is important for the hadron shielding.

The uncertainty in prompt muon production noted above for 20 TeV collisions is, of course, greater at 40 TeV. Crude upper limits can be derived from cosmic ray data. As in the 20 TeV case, two source assumptions are suggested: (a) a prompt muon to pion ratio of 0.01%, and (b) a 3mb D production cross section with a least-favorable momentum distribution. The contribution from high transverse momentum jets to D-meson and other heavy flavor production should also be explored.

In contrast to the uncertainties in production models, the models for particle transport are based on well-established physics and are considered quite reliable. Similarly, the production of radioisotopes by energetic particle cascades is well understood, as is the transport of scattered radiation through ducts and by skyshine.

4. REGULATORY AND ADVISORY FRAMEWORK

Regulatory criteria distinguish between radiation workers who are trained in radiation procedures and whose exposure to radiation is monitored, and the members of the general public who may have access to areas of potential radiation without being individually identified or monitored. The principal focus of the Workshop was on protection for the general public. These criteria are understandably much more restrictive than those for radiation workers.

In defining radiation criteria the Department of Energy distinguishes between criteria for operating a facility and criteria for designing a facility. DOE Order 5480.1A (Chapter XI) defines the radiation standards for protection of the public in the vicinity of DOE facilities. The permissible level for continuous exposure is limited to 100 mrem per year of whole-body radiation compared to an average naturally occurring background of 170 mrem per year. For non-continuous exposure the limit is 500 mrem per year. These are operational limits. To ensure that these will be met in operation, DOE specifies that facilities be designed for 20% of the permissible levels. This is an application of the policy that all radiation exposures shall be kept as low as reasonably achievable (ALARA). Since the SSC is in a design phase the relevant criteria are the 20% limits. In accordance with the ALARA policy of DOE the SSC should be designed to limit exposures to less than 20 mrem per year. For occasional exposure the maximum allowed dose equivalent for individual members of the public is less than 500 mrem in any one year. According to the ALARA policy, this implies that the SSC should be designed to limit the maximum anticipated exposure to any member of the general population to less than 100 mrem per year in the case of the hypothetical loss of a full beam discussed in Section 2b, above.

The Workshop endorses more restrictive guidelines for the SSC. The reasons for this recommendation are that

- o the selection of a design criterion which is a small percentage of the natural background would help to allay possible public concerns about operation of the facility,
- o this would be consistent with other government agencies and existing DOE facilities, which impose limits for routine operations which are small relative to the allowed maximum. For example, Fermi National Accelerator Laboratory and the Stanford Linear Accelerator Center have established 10 mrem/yr as administrative limits for routine operations. Brookhaven National Laboratory had proposed an administrative limit of 5 mrem/yr for the Colliding Beams Accelerator (subsequently not completed). The Nuclear Regulatory Commission limits exposures due to nuclear power plant operations, which are qualitatively different from accelerator operations, to 5 mrem/yr at site boundaries.

In the judgment of the participants some justification would be required, if criteria were to be adopted that differed significantly from those followed by existing facilities.

In addition to the limits discussed above, several other exposure limits must be incorporated into the design of the SSC facility. Permissible limits of radiation in ground water are controlled by radiation limits for drinking water which have been established by the Environmental Protection Agency. The maximum level of radiation from community drinking water supplies is set at 4 mrem/yr by EPA regulations. Also, the dose to the general public from radioactivity released into the air is limited by EPA regulations to less than 25 mrem/yr.

5. CONCLUSIONS AND RECOMMENDATIONS

(a.) The operation of existing multi-GeV facilities such as Fermilab and the CERN SPS has been radiologically safe, and radiation levels at site boundaries have not exceeded regulatory guidelines. It is reasonable to conclude from this that there is sufficient collective

experience available in the accelerator and regulatory community to ensure that a safe, environmentally sound facility can be built on the scale of the Superconducting Super Collider.

(b.) For the SSC design reflected in the Reference Designs Study and the Site Parameters Document the radiation at the site boundaries will be within the recommended guidelines. Radiation levels adjacent to the accelerators will be governed by the permissible levels for radiation workers as described in 4, above. Radiation levels decrease as a function of distance from their source. Given that any sources are at or below permissible levels for radiation workers, and given the distances from any potential sources to site boundaries as designed, the resultant levels at the boundaries are well below permissible levels for the general public.

(c.) Most of the radiological problems associated with the operation of the SSC can be treated as an extrapolation of the experience at existing accelerators. These include hadronic cascades, neutron leakage and transport, skyshine, and the production and transport of radioactive and noxious gases. The transport of high energy hadrons and muons is well understood, and can be calculated with confidence using existing codes. For the uniquely high-energy aspects of the problems, such as high-energy muon production, although they are not well understood, there does exist theoretical and experimental guidance on upper limits.

(d.) There is good consistency among the existing high-energy transport codes, CASIM, FLUKA82, and HETC, and between them and the available experimental data.

(e.) To evaluate SSC shielding and designs it would be desirable to have improved particle production models for prompt muon sources (D-mesons, etc.), and to extend calculations to 20 TeV, using CASIM or similar codes, for specific geometries.

(f.) Decommissioning of the SSC would not present any problems not already encountered in decommissioning other accelerators, such as the Cosmotron at BNL, and the ZGS at ANL. The radioactive components from the machine would fall under the category of "low-level" waste (LLW), which is transportable under existing DOE regulations. Ease of decommissioning should be kept in mind in the design of the facility.

(g.) It would be useful for this panel, or a similar group, to reconvene later as the SSC design and siting progress. It is recommended than an ongoing interaction between the radiological safety community and the SSC Central Design Group be maintained.

6. WORKSHOP RESOURCES

As noted in the Introduction, this report merely summarizes a great deal of discussion based on the experience of the participants, including participation in early studies of shielding for the SSC such as are included in the Cornell Workshop, and a great deal of written material provided by each of the presenters in connection with his topic. All of this material forms an integral part of the report of this Workshop. It is listed here under the topic headings as provided. The material is too extensive to reproduce for inclusion in the report, but it is on file at the Central Design Group.

Presenter		Material
Stevenson, G.R.		"Presentation on LEP/LHC" (viewgraphs).
	Fas84	A. Fasso, K. Goebel, M. Hofert, H. Schonbacher and G.R. Stevenson, "Radiation Protection Considerations for a Large Hadron Collider," CERN Internal Report TIS-RP/IR/84-20 (28 March 1984).
	Fas84	A. Fasso, K. Goebel, M. Hofert, H. Schonbacher, and G.R. Stevenson, "Environmental Considerations for a Large Hadron Collider," CERN Technical Memorandum TIS-RP/TM/84-16 (9 March 1984).
Hinchliffe, I.,		"Presentation on 20 TeV Physics," (viewgraphs).
	Mac	MacDermott, M. "A Review of Charm Hadroproduction," Rutherford Appleton Laboratory Report.
Van Ginneken, A.		"CASIM, A 'Weighted' 3D Monte Carlo to Study Hadron Cascades in Bulk Matter," (viewgraphs).
Alsmiller, R.,		"High Energy Transport Code, HETC," (viewgraphs).
Ranft, J.,		"FLUKA82," (viewgraphs).
	Ste85	G.R. Stevenson, P.A. Aarnio, A. Fasso, J. Sandberg, J. Ranft, "Comparison of Measurements of Angular Hadron Energy Spectra, Induced Activity and Dose with FLUKA82 Calculations," CERN TIS-RP/158/CF (1985) (draft).
Casey, W.R.,		"Radiation Guidelines," (viewgraphs).
		P. J. Gollon, W. R. Casey, "ISABELLE Shielding Criteria and Design," Health Physics 46, 123-132 (1984).
Toohig, T.E.,		"SSC Parameters Relevant for Environmental Radiation," (viewgraphs).
	Too85	T.E. Toohig, "Land Acquisition Requirements for the SSC: Background for the Site Parameters Document," SSC Central Design Group Report SSC-N-6 (22 April 1985).
	Too85	T. E. Toohig "SSC Parameters for Radiation Calculations Derived from the RDS," SSC/CDG Internal Memo (5 July 1985).
	Mor85	V. More, and T. Toohig "Site Layout - Clustered IR's," Conceptual drawings, SSC/CDG (Sept. 1985).

Jones, L.W., "Continuous Sources at Intersection Regions," (discussion paper).

"Concerns Regarding the Proposed Superconducting Super Collider (SSC)," Michigan Dept. of Public Health.

McCaslin, J., "Radiation Measurements in the Tevatron Tunnel," (viewgraphs).

Cossairt, J.D., "Hadron and Muon Shielding: Comparison of Experimental Data with Calculations," (viewgraphs).

J.D. Cossairt "Design Considerations for Personnel Access Penetrations for the Superconducting Super Collider," FNAL TM-1307 (April 1985).

J.D. Cossairt, A.J. Elwyn "Shielding Considerations for Fixed Target Use of the SSC," SSC Workshop on Fixed Target Physics, The Woodlands, TX (Jan. 1984).

J.D. Cossairt and L.V. Coulson, "Neutron Skyshine Measurements at Fermilab," Health Physics 48 175 (1985).

J.D. Cossairt, J.G. Couch, A.J. Elwyn, and W.S. Freeman, "Radiation Measurements in a Labyrinth Penetration at a High Energy Proton Accelerator," Health Physics 49 907 (1985).

J.D. Cossairt, S.W. Butala, and M.A. Gerardi, "Absorbed Dose Measurements at an 800 GeV Proton Accelerator: Comparison with Monte Carlo Calculations," Nuclear Instruments an Methods in Physics Research, A238 (1985) pp. 504-508.

Ste85 G.R. Stevenson, "Shielding of Extended Targets at Proton Energies of Greater than 3 GeV," CERN Report TIS-RP/grs-01 (19 Sept. 1985).

Stevenson, G.R. "Muon Transport Calculations," (viewgraphs).

Loh85 W. Lohmann, R. Kopp, and R. Voss, "Energy Loss of Muons in the Energy Range 1-10000 GeV," CERN Report 85-03.

Mas83 M.A. Maslov, N.V. Mokhov, and A.V. Uzunian, "Calculation of Muonic Fields Around Large High Energy Proton Accelerators," Nucl. Instrum. Methods 217, 419 (1983).

Ste79 G.R. Stevenson, "A User Guide to the MUSTOP Program," CERN Technical Memo HS-RP/TM/79-37 Rev. (30 July 1979).

Ste81 G.R. Stevenson, "A Description of the TOMCAT Muon Transport Program," CERN Internal Report HS-RP/IR/81-28 (30 April 1981).

Ste82 G.R. Stevenson, "Energy Loss Due to Muons," (private notes).

Ste83 G.R. Stevenson, "Dose and Dose Equivalent from Muons," CERN Report TIS-RP/099 (1 March 1983).

Ste84 G.R. Stevenson, "Calculations of dE/dx and Muon Ranges in Concrete and Earth," Cern Report TIS-RP/IR/84-07 (27 Jan. 1984).

Ste85 G.R. Stevenson, "Muon Shielding," IAEA Manual, Chapter 4.5 (IAMUSH) (8 Oct. 1985) (draft).

Zup85 C. Zupancic, "Physical and Statistical Foundations of TeV Muon Spectroscopy," CERN Report CERN-EP/85-144 (13 Sept. 1985).

Cossairt, J.D., "Presentation on Test Beams," (viewgraphs).

APPENDIX I

WORKSHOP ON ENVIRONMENTAL RADIATION

Central Design Group - 90/4040

October 14 - 18, 1985

A G E N D A

Monday, October 14

AM--Setting the Framework

9:00	Welcome	M. Tigner
9:15	Goal of Workshop	J. Sanford
9:45	LEP/LHC	G. Stevenson
10:30	BREAK	
10:45	20 TeV Physics	I. Hinchliffe
11:30	MultiTeV Muon Data	L. Jones
12:15	LUNCH	

PM--Tools, Extend to 20 TeV

1:30	Program CASIM	A. VanGinneken
2:15	Program HETC	R. Alsmiller
3:15	BREAK	
3:30	Program FLUKA	J. Ranft
4:15	Meditation	
5:00	Wine and Cheese	

Tuesday, October 15

AM--SSC Parameterization

9:00	Radiation Guidelines	W.R. Casey
9:45	SSC Parameters	T. Toohig
10:30	BREAK	
10:45	Calculate Loss	A. VanGinneken
12:00	LUNCH	

PM--Experimental Results

1:30	Draft Radiation Paper	L. Jones
2:30	Radiation in Tevatron Tunnel . . .	J. McCaslin
3:30	Hadron and Muon Shielding	D. Cossairt
4:15	Meditation	

Wednesday, October 16

AM--Procedures and Tasks

9:00	Muon Transport Calculations . . .	G. Stevenson
9:45	Procedures/Report Prep.	
12:00	LUNCH	

PM--Working Groups

1:00	Working Groups
4:30	Wine and Cheese

Thursday, October 17

AM--Working Groups

9:00	Test Beams	D. Cossairt
9:45	Working Groups	
12:30	CHINESE LUNCH	

PM--Working Groups

1:30	Working Groups
3:00	Reports of Working Groups

Friday, October 18

AM--Reports of Groups

9:00	Summary Report	G. Stevenson
	Final Drafts/Wrap-up	

APPENDIX II

Computer Codes for Accelerator Radiation Calculations

Code: CASIM

Author: A. VanGinneken

Location of code in USA: Fermilab

Description: Monte Carlo for high energy primary protons. Tracks cascade of particles down to 50 MeV through geometries of arbitrary composition and magnetic fields. CASIMU version tracks muons generated by the cascade. AEGIS subroutine follows electromagnetic showers.

Output: Star and energy density contours.

Advantages: Interaction processes during transport permit tracking of 20 TeV primaries. Weighting techniques greatly reduce computer running times.

Code: FLUKA82

Author: J. Ranft, G. R. Stevenson, P. Aarnoi

Location of code in USA: SLAC (contact W. R. Nelson)

Description: Monte Carlo for high energy primary hadrons. Tracks cascade of particles down to 50 MeV through materials.

Output: Star density, energy deposition density, and secondary particle distribution.

Advantage: Comprehensive production model including production of resonances which should be valid to 20 TeV and above.

Code: HETC

Author: R. G. Alsmiller, Jr., T. W. Armstrong, T. A. Gabriel

Location of code in USA: ORNL, LBL, SLAC

Description: Monte Carlo for high energy nucleons and pions. Tracks cascade of particles through materials down to thermal neutron energies.

Output: Particle flux distributions and activation product distributions.

Advantages: Fully analog transport. Lower energy neutron transport included.

Code: TOMCAT

Author: G. R. Stevenson

Location of code in USA: SLAC, LBL

Description: Analytical code for tracking high energy muons through materials.

Output: Particle and energy density contours.

Advantage: Fast and user friendly.

APPENDIX III

SSC-N-127

Environmental Radiation Workshop

RADIATION CONSIDERATIONS FOR ACCELERATOR RING SEPARATIONS

1. Introduction.

The Workshop was asked to consider the requirements to allow access to the Collider Ring with the High Energy Booster (HEB) operating and to the HEB with the Collider Ring operating. The use of the HEB for test beams independently of the operation of the Collider Ring makes the former condition desirable, while the very long store time (a day) for beam in the Collider Ring makes the latter desirable.

2. Radiation Through Beam Channels.

The first requirement to allow access to one tunnel while the adjacent accelerator is operating is that the beam channels between them be sealed off with redundant safety devices. A fail-safe beam stopper closing off a narrow place in the channel is one of these. The second is a bending magnet string in the channel situated so that the beam cannot traverse the channel into the adjacent accelerator with the magnets de-energized. With a properly designed channel these two critical devices provide the accepted two levels of redundancy for safe operations.

Along with the critical device requirement to close off the beam channel from direct radiation, it is necessary to stop radiation traveling between the accelerators outside of the beam channel. The Workshop recommended that the CERN practice be followed of interposing a minimum of ten meters of soil

shielding closing off the channel between the two accelerators with the only penetration through the shield being a beam pipe. The beam-stopper called out above is placed just upstream of this pipe and acts to close it off.

3. Hadron Penetration Through the Shielding.

The hadron shield around the Collider Ring is defined to be a minimum of 6 meters thick. This is calculated from considerations of a hypothetical total loss of beam at a point in the Ring. This sets 6 meters as the minimum separation between the Collider Ring and the point of closest approach of the extraction enclosure in the HEB. If a beam dump is placed in the extraction line within the HEB enclosure this separation would be increased to a minimum of 8 meters to account for the increased neutron flux from the full intensity 1 TeV beam striking the dump.

4. Muon Penetration Through the Shielding.

The hadron radiation zone is symmetric around the Collider tunnel, so that it is irrelevant whether the required separation described in 3., above, is in the horizontal or vertical plane or in between. The radiation zone for muons from the collider, however, is defined by a narrow cone of muons extending for the order of 2 kilometers along the tangent to the accelerator orbit. This sweeps out an exclusion zone of order 200 meters to the outside of the Collider Ring in the plane of the ring. To allow access to the HEB tunnel while the Collider is operating the HEB tunnel must be inside the Collider ring or out of the plane of the Collider, or more than 200 meters outside of the Collider orbit. The last choice would require that the transport line elements within 200 meters of the Collider would not be accessible during Collider operation.

The muon radiation zone from the HEB is much less restrictive than that from the Collider both because of the lower intensity of the HEB and its lower energy. The separation dictated by the hadron shielding discussed above is, then, adequate also for muons from the HEB operation penetrating the Collider tunnel.

5. Conclusions.

The minimum distance of approach between the HEB and Collider enclosures is 6 or 8 meters, depending upon the inclusion of a beam dump in the HEB extraction line or not.

If the two accelerators are in the same plane, then the HEB should be on the inside of the Collider ring unless a minimum separation of order 200 meters is acceptable.

Under these conditions, with a properly designed beam channel containing redundant critical devices, typically a fail-safe beam stop and a critical bending magnet power supply, either ring is fully accessible while the other is operating, even at full intensity.

An example beam channel incorporating the recommendations of the Workshop is shown in Figure 1.

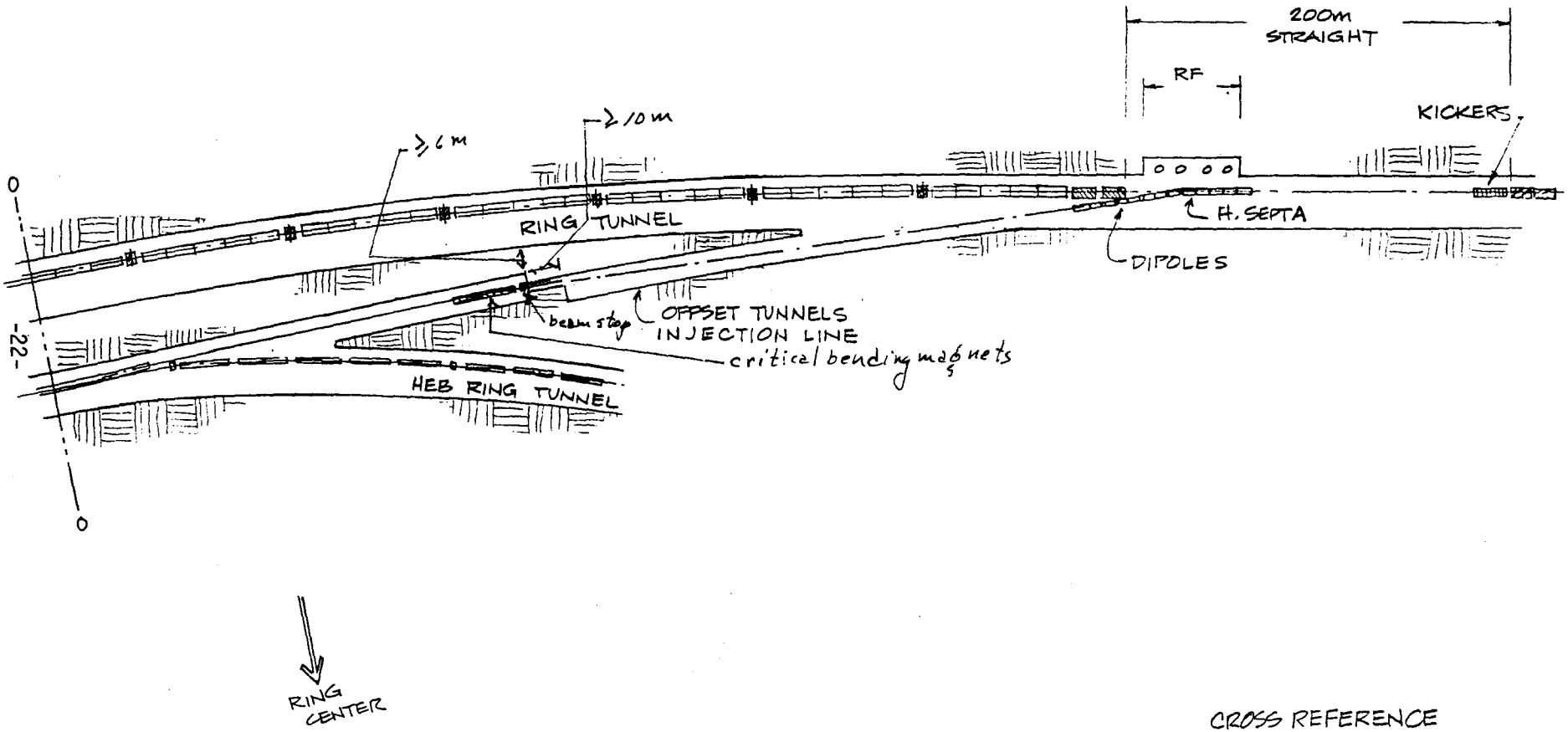

Figure 1

CROSS REFERENCE
PLAN DRG. B4M084

SSC CENTRAL DESIGN GROUP	
DRAWING NO. B3M090	TITLE: TRANSPORT LINE PLAN HEB/MAIN RING - UPPER