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NEUTRON FLUX MEASUREMENTS IN THE TEVATRON TUNNEL

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Summary

Preliminary measurements indicate that the neutron flux associated with beam loss in the SSC will degrade semiconductor components in the tunnel on a time scale marginally short compared with the lifetime of the machine [1]. Although these measurements [2] resulted in dependable spectra and the observation that neutrons were a more serious threat than ionizing radiation, they failed to correlate the observed flux with the proton loss rate. As a result, it is quite important to obtain a better experimental understanding of the situation: In the worst case 400 electronics racks in the SSC tunnel (one at every other spool piece) must be recessed into a shielded cave, the quench protection diodes must somehow be brought out of the cryostats to shielded locations, and alternate designs must be chosen even for temperature sensors. To establish the loss rate correlation and clarify several other issues, we propose new measurements starting in the fall of 1986. In conjunction with the measurements, the ORNL cascade simulation group (R. G. Alsmiller and T. A. Gabriel) has agreed to model the problem in their Monte Carlo programs, with the goal of obtaining agreement between theory and experiment in this complicated situation. We feel that only with (a) experimental results with enough detail and redundancy to be trustworthy, and (b) confirming theoretical calculations, can we really understand the Tevatron situation and safely extrapolate to the SSC case.

1. Scientific Justification

Measurements made in the Tevatron tunnel (A48) in the fall of 1985 (Experiment T-766) produced reliable neutron energy spectra, and identified the neutron component as the predominant radiation against which the electronics in the tunnel must be shielded [2]. Nearly identical spectral shapes were exhibited from run-to-run, and counting rates correlated well with stored beam current during coasting beam periods. However, there was no way to correlate the neutron flux with the proton loss rate, which was presumably due to beam-gas collisions in the single dipole length of warm beam pipe immediately upstream from the neutron spectrometer. During the final hours of the Tevatron running period we allowed the pressure to rise in this section by turning off the vacuum pumps and tried to note a change in counting rates. No useful data were obtained from this part of the experiment. Rate changes were not statistically significant, and the pressure rise, as measured at one end of the warm section (rather than at its mid-position), was insignificant. A flying wire target was not available at A48.

Somewhat arbitrarily, a 300 hr beam lifetime was assumed in relating the neutron flux to a proton loss rate. An extrapolation with energy was made using FLUKA, the CERN cascade simulation program. (We believe this step to be dependable.) With an assumed 350 hr beam loss lifetime for the SSC, we then obtained 8000 $cm^{-2}s^{-1}$ for the neutron flux in the SSC tunnel under standard operating conditions, or $0.8 \times 10^{11} cm^{-2}$per standard 10^7s SSC "year." With the onset of electronics mortality expected at $\gtrsim 10^{12} cm^{-2}$, this annual fluence is indeed serious—particularly in view of the large uncertainty associated with it.

For these reasons, the SSC Central Design Group regards further measurements as essential. The highest priority will be given to understanding the source of the neutron progenitors, *e.g.* by observing the dependence of the flux on the pressure of the warm section. Since this experiment is being carried out in conjunction with cascade modeling by the ORNL group, we are we are also interested in understanding how flux and spectra scale with distance from the magnet, tunnel dimensions, and longitudinal distance, and accordingly propose a minimal set of measurements with modified counter positions and arrangements.

2. Description of the Experiment

We propose that the new set of measurements be made at Sector A17 following installation of the large detector in the CDF hall in November of this year. Most of the apparatus will be that used in 1985. It consisted of an 8-sphere "Bonner spectrometer," as described in Ref. 2, supplemented by two identical BF_3 moderated neutron counters. For the present run, replacement of the moderating spheres with moderators of identical radius will speed measurments once spectra are known, and NaI(Tl) counters will provide a separate measurement of ionizing radiation.

Downstream of A17 (from a proton's point of view) is a 14.5 m section of warm beam pipe where two dipoles have been "omitted." In the center is a flying wire device, and with the addition of a controlled leak and ionization gauge in the center, the gas column in the warm section can be changed and monitored. The spectrometer will be arranged downstream of this region, opposite cold dipoles. Measurements will be obtained at two or more longitudinal positions and two or more distances from the magnet with the full spectrometer; to the extent that spectra are the same in different positions rate measurements can then be expedited by using spheres with identical moderators.

We will make the following measurements:

1. Correlation of counting rates with pressure in the warm bore, preferably using a hydrogen leak.

2. Correlation of counting rates with beam loss using a flying tungsten wire target.

   (There are interpretative difficulties with both experiments: Hydrogen is the preferred target since it now appears that collisons with hydrogen will dominate in the SSC bore tube. However, accurate estimation of column height may be difficult, given one or at most two pressure measurement points. On the other hand, we are uncertain about scaling to a high-Z nucleus.)

   The most important goal of the experiment is relating the observed neutron rates to known proton loss rates; we feel that the redundancy between approachs 1 and 2 is essential.

   Both of these experiments will initially be done with the full spectrometer.

3. Measurement of the neutron spectrum some distance downstream of the original location. Since albedo neutrons should be relatively more important, the spectra there might be visibly softer—and in any case, the measurement will check the simulation result for the same situation.

4. If the spectra are essentially independent of longitudinal position, measure the longitudinal distribution of flux downstream of the warm sections using 5-inch moderators on each of the 8 Bonner detectors.
5. Measurement of the radial distribution (across the tunnel) in order to understand the relative values of the direct contribution from the magnets and albedo contribution from the tunnel walls. A single measurement with the spheres close to the Tevatron ring will probably suffice.

3. Experimental impact on collaborators and Fermilab

3.1 PERSONNEL

The participants are as follows:

SSC Central Design Group: (FTS 451-6788)	Don Groom
LBL Radiation Physics Group: (FTS 451-5251)	Joe McCaslin, spokesman for the experiment Rai-ko Sun Bill Swanson
Fermilab:	Alex Elwyn, X 4626 Bill Freeman, X 3020 Hans Jostlein, X 4468 Craig Moore, X 4427 Peder Yurista, X 4437

3.2 EQUIPMENT

Most of the necessary equipment is on hand. Cable extensions are being fabricated at LBL, and the necessary cable connectors will be purchased from LBL stores. In addition to the counters and cabling, certain LeCroy electronics modules will be supplied from LBL and SSC Central Design Group resources.

As with the T-766 experiment, we will ask FNAL to supply the following items:

1. 50 MHz dual trace oscilloscope. (Faster scope preferred.)
2. Isolation transformers, one at 200 W, the other at 2KW minimum.
3. Flying wire at A17 and assistance in set-up and operation.
4. Pressure gauges between warm sections, logging and remote control of vacuum pumps at A17, and assistance in operation and interpretation.

5. Controlled leak between warm sections, with remote control.
6. Two LeCroy 222 Dual Gate Generators.
7. Counting area with minimum of two 6-ft racks, table and 2 chairs.
8. Accelerator status monitor.
9. Specially designed gating module. This should be re-evaluated by Dave Beechy as to its suitability for present Tevatron operation in the intended area.
10. It would be highly desirable to obtain support equipment for the NaI counters at Fermilab. This consists of cabling (450 feet (patches OK) of RG58 or equivalent with BNC connectors for each of two counters and of RG59 or equivalent with SHV connectors for each of two counters), HV supply (2 channels, *e.g.* Bertan's), and 2 MCA's (*e.g.* LeCroy qVt's with manual readout). If these items cannot be found at Fermilab, it may be possible to obtain at least some of them from SLAC.

3.3 Time Request

The experiment will be run entirely as a parasitic operation, and should have no visible impact upon accelerator operation. Installation will occur during the one-week down period for CDF installation, which is now scheduled to begin 11 November 1986. We will require tunnel access during otherwise scheduled down time in order to move apparatus.

3.4 Other Considerations

1. During the down-time week presently scheduled for 11 November, we will pull cables and do other necessary installation.. While we will do the work ourselves, advice may be needed concerning routing, *etc.*
2. For the reasons explained above, counters will need to be moved frequently. The equipment is light and placement is not critical, but obtaining tunnel access (*e.g.* one of the limited number of keys) has in the past presented problems. We are willing schedule our accesses in "off hours" if this will help the problem.

3.5 EXPERIMENT-ACCELERATOR PROTOCOL

1. No magnetic elements wil be used.
2. The equipment described above may at times partially obstruct movement of the magnet vehicle (but not personnel) in the tunnel. The detectors are light and can be moved aside by one person if circumstances require.
3. All cables will be controlled by the Experiments Support Department (ESD). This includes authorization of types, routing, labeling, and installation. Basic labeling will be provided by LBL/CDG, but FNAL may add labeling at their discretion.
4. One NIM crate containing fanouts of low voltage power for counter preamplifiers will be located in the tunnel, and powered by tunnel AC power through an isolation transformer. No other utilities underground are required.
5. Experimental apparatus to be interfaced with the AD control system will be coordinated with the Head of the AD Controls Group (Dixon Bogart) so that standard modules can be used.
6. All access to accelerator tunnel experimental areas will be strictly controlled by the Accelerator Division via a protocol which is to be developed by the ESD.
7. All experimenters must attend the safety training courses defined by the AD head. These courses presently include ODH, Accelerator New Employee Radiation and Accelerator Controlled Access.
8. It is understood that successful operation of the basic accelerator functions has priority over experiments.

3.6 BUDGET

Budget needs for this experiment are included in the CDG/Fermilab Agreement for SSC work in FY 1987. No need for more than incidental supplies is anticipated, which can be obtained through an SSC account to be established with Fermilab.

REFERENCES

1. *Conceptual Design of the Superconducting Super Collider*, SSC Central Design Group (J. D. Jackson, ed.), SSC Central Design Group Report SSC-SR-2020 (March 1986).
2. Joseph B. McCaslin, Rao-Ko Sun, William P. Swanson, Alexander J. Elwyn, William S. Freeman, and Peder M. Yurista, SSC Central Design Group Report SSC-58 (October 1986).

Appendix I:
Memorandum from D. E. Groom to D. A. Edwards, dated 03 September 1986, regarding the proposed measurements.

SSC CENTRAL DESIGN GROUP MEMO 03 September 1986

TO: Don Edwards

FROM: Don Groom

SUBJECT: Neutron flux measurments in the Tevatron tunnel

This is to confirm this morning's telephone conversation.

We find the need for good neutron measurements in the Tevatron tunnel increasingly urgent, and propose making such measurements this fall in collaboration with personnel from LBL and Fermilab.

Last fall's measurements were quite successful.* A Bonner sphere spectrometer was installed and operated, reliable spectra were obtained, and the measured flux was quite stable when normalized to the number of protons in the machine. The biggest single problem was that proton loss rates were really not known. (How many neutrons per lost proton at the Tevatron?) We also have no experimental knowledge of the longitudinal distribution, or whether the flux has the expected dependence upon distance from the magnets.

We would like to resolve these problems with new experiments, with particular emphasis upon correlating the neutron flux with proton loss rate.

Some shortcuts are possible: Although we should confirm last year's spectral measurements, once the spectrum is known only one sphere is necessary to measure flux, at least at a fixed distance from the magnet. We will therefore equip all eight detectors with polyethylene spheres of the same radius, so that the spatial distribution of the flux can be measured more quickly.

We would like to measure the following:

1. *Loss Rate.* If possible, the detectors will be positioned along the cold magnets downstream of a warm straight section, in which a flying wire is also installed. Pumps will be turned off to observe the relationship between flux and pressure. The pressure bump should be minor enough that it will not interfere with collider operation, but if there is concern the measurements can be made near the end of fills. Flying wire

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* J. B. McCaslin, R-K. S. Sun, and W. P. Swanson; J. J. Elwyn, W. S. Freeman, and P. M. Yurista, SSC Central Design Group Report No. SSC-58 (1986).

measurements will provide the necessary redundancy in correlating flux with loss rate; these should obviously be made only near the end of fills.

2. *Longitudinal Dependence.* Both the warm gas section and the flying wire are essentially point sources, while we are interested in understanding the flux from a distributed source, or, equivalently, the average over the longitudinal distribution. The eight identical spheres will therefore be arranged in the longitudinal direction with each the same distance from the magnets, so that the distribution can be obtained with a minimal number of accesses.

3. *Dependence on Distance from the Magnets.* According to our present understanding, most of the relevant neutron flux (4/5 or so at the tunnel wall) consists of albedo neutrons from the tunnel walls, with an isotropic distribution inside the tunnel. The direct flux should depend inversely as the distance from the magnet. Measurements as a function of distance from the magnet should confirm this dependence and permit separation of albedo and direct flux.

   Since the spectrum of direct neutrons will be harder than that of albedo neutrons, spectra with the full compliment of spheres should be obtained at two or three radii.

4. *Neutron Intensity in the IR Halls.* If feasible, and if it appears that useful measurements can be made, neutron flux measurements at various positions in the CDF experimental hall would be useful. (At the SSC the flux in the IR halls is many times that in the tunnel, and very likely poses a serious problem for detector electronics. The shielding effect of detector components is important, but is very difficult to calculate.)

cc: Maury Tigner
Peter Limon
Tim Toohig
Rich Orr
Joe McCaslin
Bill Swanson