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Switchyard Losses and Transport Efficiency for High Intensity Protons with Unsplit Beams

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SEB Transport Efficiencies and Beam Losses in Switchyard

Study Period:	30 June 1994
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Study:	Switchyard Losses and Transport Efficiency for High Intensity Protons with Unsplit Beams

Introduction:

The 1994 High Energy Physics run provided the highest intensity beams ever achieved for a proton synchrotron. Various observations during the run called into question the reliability of the instrumentation at these high intensities and in the measurment of the transport efficiencies with split beams to all four beam lines. Various methods of estimating these efficiencies gave results which varied from as good as 85 - 90 % total efficiency to as bad as 50 - 60 % total efficiency. Calibrations of the target SEC's were made from foil emulsions performed at the end of June. Based on the SEC calibrations and comparing to the AGS current transformer just before extraction, it was noted that the percentage of beam lost rose dramatically for AGS late CBM intensities between 32×10^{12} and 36×10^{12} ppp. (1) This measure of loss varied from 10 % to as high as 35 %. Meanwhile the "standard" measure of switchyard losses showed little or no change over this range of intensities. This "standard" is based on the normalized 'calibrated' sum of the losses in the switchyard. These losses indicated the transport efficiencies with four split beams varied between 11.5 % loss and 17.5 % loss over a range of intensities from 28×10^{12} ppp to 37×10^{12} ppp.

The purpose of this studies report is to try to understand further what the losses in switchyard are telling us and whether a measure of transport efficiency can be established based on the loss monitors.

The Study:

Beam was transported down individual beam lines (unsplit) and, with a limited amount of tuning, beam losses were minimized. A total of 12 sets of data were taken. Of these sets 5 were with all the beam down C line, 4 were with all the beam down D line, 2 were with all the beam down B line, and one was with a D/A split. Only the D and C line data sets were analyzed for this report. The 2 B line data sets and the D/A split data set were not analyzed simply because they were not complete enough to use for analysis (see preliminary observation number 7 on next page). The data is tabulated in Tables VII & VIII and the CLYDE calibration constants are shown in Table IX.

The 5 C line sets of data ranged in intensities from 8 TP to 15 TP. Three of these were taken with all the beam on the C target and the other two were with all (or most) of the beam off the C target. The 4 D line sets of data ranged in intensities from 7 to 15 TP. Of these, two were with all the beam off target and two with all the beam on target.

The data consists of printouts of 'CLYDE' data, all of which consist of normalized and 'calibrated' numbers. In order to render 'raw' information from this data, the normalizations and calibrations were taken out. Because of the complexity of some of the calculations, only the data from the long loss monitors was analyzed. It is not possible to extract the raw point loss monitor data because values displayed on CLYDE are derived from multiple subtractions.

A list of definitions is included on page 8. A list of proposed studies is included on page 9.

Analysis:

The following starting assumptions were made:

1. The AGS current transformer is calibrated and correct.
2. The extraction inefficiency calibration and measurment is correct.
3. The target SEC's are calibrated and correct.

Preliminary Observations:

1. Both DSEC and CSEC give significantly different answers between beam on target and beam off target. See figures II - V. Certainly this undermines the third assumption. The CSEC goes down by 5 % (in going off target) and the DSEC goes up by 17 % (in going off target).
2. All long loss monitors , except DL24L, AL28L, and AL22L, have the same calibration constants in CLYDE; yet (for beam on target data only)

   for D only: LLS(raw) = $290196/10^{12}$ ± 2935 (1% standard deviation) loss

   for C only: LLS(raw) = $431358/10^{12}$ ± 63512 (15% standard deviation) loss

   See figures VI and VII. The implication is that long loss monitors in D line are less sensitive than those in C line. Certainly the geometries are different for many of the monitors. For example the loss monitors around the big bend in D line have a significant amount of iron between possible loss points and the monitors.
3. Both CL44L and CL47L appear to count ~2-3x greater with beam on C target than with beam off C target. Both these monitors are in the cave close to the target.
4. DL39L does not change with beam on or off the D target. This is the closest long loss monitor in D line to the D target.
5. With all the beam in D line AL28L shows significant beam loss. Niether AL22L nor AL24L show any loss. The ASEC shows no counts.
6. ACV shows very much the same value as AL28L.

   ACV = AL28L - AL304

   It seems AL304 was broken (or something), but it was not being subtracted from AL28L.
7. The B line data is not completely useless and there is some qualitative information which should be noted. One problem with this set of data is the intensity the BSEC reports is greater than what is observed at the time of extraction on the AGS current transformer. The switchyard and ring cave loss monitors do scale up nicely with intensity. In this case the long losses are dominated by the SWCV (as much as 70 %). It is worrysome, though, that the BCV losses do not give sensible information. What is meant here is that the long loss monitors in the B cave show large negative values when there is no beam in B line, and the fact that, compared to the other caves, the losses in BCV are so small when there is beam in B line. Certainly the possibility that the transmission to B target was exceedingly good cannot be discounted, but the fact that the SEC reads higher than LBM and the unusual behavior of the loss monitors in the cave, serious doubt is cast on the believability of any of that information.
8. There are some inconsistancies in the data which belie our confidence. For example one ought to be able to extrapolate backwards and derive the value of LBM from T/I and the sum of the target SEC's. By inspecting the data it is easily seen that this doesn't always work. Another inconsistancy arises when one tries to derive the value of CION, for example, from the CCV and the long loss monitors. One explaination may be that the data doesn't represent the same AGS pulse. The CBM may be sampled one or two AGS pulses ahead of the loss monitors, for instance.

CE010 SEC:

A plot of the raw counts vs LBM * (1 - ineff.) shows that CE010 = 750 counts /10^{12} ppp.

The value from the CLYDE constants is 763.4. (see Figure I). The data shows the C10 response is almost perfectly linear relative to the derived estimate for the extracted beam over the entire intensity range. One may notice that the CLYDE data set values for the efficiency and inefficiency do not reflect this well. This is because the calibration constants in CLYDE were corrected in the time between data sets. The fact that the slope of this line agrees with the value in CLYDE is expected. Varying the intensity does not provide a calibration, in this situation.

Estimates based on Long Losses:

The integrator offsets for all the loss monitors were very small (background counts of 5 - 10 / 3.2 seconds) and so it was assumed there was a zero intercept.

If we use the above calibrations for LLS (prelim. observ. #2) to determine beam lost in the switchyard then we get the following based on beam to C only. The value displayed for "Calc. loss LLS" is the calculated amount of loss based on the above calibrations, given in TP. The "% lost + ineff." is the percentage of total beam lost from prior to extraction to the targets. In a well calibrated and normalized world this value should agree with "(1-T/I) " where T/I is a number displayed on CLYDE.

Table I. Estimate of total loss based on raw LLS from CLYDE

Condition	LBM(1 - ineff.)	Calc. loss LLS	% lost + ineff.	(1-T/I) (CLYDE)
ABCD split	7.76 TP	1.45 TP	22.9 %	6 %
ABCD split	11.16 TP	1.16 TP	17.5 %	10 %
ABCD split	32.20 TP	3.22 TP	14.9 %	28 %
ABCD split	36.39 TP	4.70 TP	19 %	15 %

For beam to D only we find:

Condition	LBM(1 - ineff)	Calc. loss LLS	% lost + ineff.	(1-T/I) (CLYDE)
ABCD split	7.76 TP	2.15 TP	31.6 %	6 %
ABCD split	11.16 TP	1.73 TP	22.8 %	10 %
ABCD split	32.20 TP	4.79 TP	18.6 %	28 %
ABCD split	36.39 TP	6.99 TP	23.2 %	15 %

The disparity between the two calibrations causes a significant difference in the amount of measured beam lost. Obviously using the same calibration coefficient for all long loss monitors is wrong. Independent of this there is also no correlation between T/I and the LLS.

We estimated the amount of beam lost based on the difference between LBM(1-ineff.) and Target SEC for beam ON target. For the data sets the loss monitors indicate a relatively constant percentage beam loss. For D-line the efficiency was approximately 84.3 %. For C-line the efficiency was approximately 95 %. If we take the total sum of all long loss monitors and divide by the amount of beam lost, based on the above percentages, we get a fairly good constant vs intensity.

For beam to D-only we find:

LBM(1-ineff)	long loss/beam lost
6.9	277904
13.5	286627
15.2	276327
15.2	273005

For beam to C-only we find:

LBM(1-ineff)	long loss/beam lost
8.56	435965
8.70	498000
15.5	472245

These constants are similar to the constants on the previous page, which is encouraging. They won't be used as calibration constants. But they do show that the conditions were fairly stable during the study, with variations of the order of 10 - 15 %.

Calibrating Losses:

This data set consists of relatively constant percentage losses over a range of beam intensities. This is not the prefered method for calibrating loss monitors. The proper method is to create local losses and measure the response of the loss monitors as a function of the change in measured beam intensity after the loss point. The same equations apply, but the method for doing the calibrations is different. If one assumes that the loss monitors do not have the same calibrations, though, then it is possible to extract some relative calibrations. This can only be true if it is not possible to arrive at the same equation for each intensity change after normalization. Due to the limited amount of data it is not possible to calibrate all the loss monitors, but there should be sufficient information to calibrate blocks of loss monitors. To do so we make the following assumptions:

0. loss monitors do NOT have same calibrations (1st order) and losses do not increase linearly with intensity (2nd or 3rd order) - this simply reflects the fact that beam size is not constant, but grows as the intensity increases.
1. Assume BCV and ACV have average calibration of D and C.
2. Use measured transport efficiencies; E.G., Δ SEC = (1 - Eff.) LBM (1 - XINEFF.)
3. The ACV loss is known to be in error. Assume the counts are a factor of 10 too high.

The sum of the long losses is related to the total beam lost,

$$\Delta SEC = \sum_{n=1}^{m} l_n C_n \qquad \text{Eq. (1)}$$

where l is the loss and C is the calibration constant.

Using the transport efficiencies above and the unnormalized cave losses reported by CLYDE we find the following:

Loss(C10-CSEC) = (1 - 0.950) LBM (1 - XINEFF)
Loss(C10-DSEC) = (1 - 0.843) LBM (1 - XINEFF)

and,

Loss(C10-CSEC) = $l_{RN} C_{RN} + l_{SW} C_{SW} + l_{CV} C_{CV}$
Loss(C10-DSEC) = $l_{RN} C_{RN} + l_{SW} C_{SW} + l_{DV} C_{DV}$

The values used for l were the CLYDE values for that particular cave (e.g., RNSW) multiplied by the value of SEB and divided by (long loss monitor calibration constant). Except for the DCV and CCV values, this number should be no different than for summing up the individual loss monitors for each particular cave. The DCV and CCV values include the subtraction of a loss monitor which resides under the targets.

Table II summerizes the data used. The RN constants derived for beam to C-only are consistent with those for beam to D-only, the constant for SWCV is a factor of 10 larger for beam to D-only. It is expected that the constants for the two caves (CCV and DCV) would be different since the geometries are much different (and there are more loss monitors in D).

Table II. Data for determining calibration constants

Loss(C10-CSEC)	RNSW	SWCV	CCV	Condition
0.4281	41755	103865	26619	Off T
0.4349	39653	113903	37258	Off T
0.7736	74043	188174	* 76873	1/4 On T
0.4334	40090	107774	136149	On T
0.4305	41488	105295	130240	On T

* Value scaled by x3.21/x0.88 to give equivalent for on/off target.

Loss(C10-DSEC)	RNSW	SWCV	DCV	Condition
1.084	52742	31434	208858	Off T
2.128	91465	63736	431254	On T
2.407	103300	74320	473028	On T
2.381	101768	69387	500050	Off T

Table III. Constants derived from Table II data (units are TP/count)

Constant	C On T	C Off T	D 1st 3 points	D 2nd 3 points
C_{RN}	3.4e-6	6.2e-6	5.5e-6	9.4e-6
C_{SW}	2.3e-6	1.5e-6	13e-6	10e-6
$C_{C/DV}$	0.33e-6	0.11e-6	1.9e-6	1.4e-6

If we now assume all the SWCV loss monitors have the same calibration except for the DL17 and DL20 loss monitors, can we descriminate between the two sets of constants? Table IV show the data in which the cave losses shown are calculated by summing the respective loss monitors for those caves.

Table IV. Data based on summing individual loss monitors.

Condition	Loss	RNSW(raw)	SWCV(raw)	C/DCV(raw)	DL17+DL20
C off T	0.428	42016	104388	37057	783 (0.75%)
C off T	0.435	39654	113903	59879	798 (0.7 %)
C 1/4 On T	0.774	74042	188647	* 314566	1415 (0.75 %)
D only	1.084	52742	31436	200843	15401 (49 %)
D only	2.128	91465	63736	424575	31454 (49 %)
Donly	2.407	103300	73852	441629	35991 (49 %)

* scaled by x1.8/÷3.62 to correct for beam on/off target.

There are a number of things to be noted with respect to the SWCV losses. For all the beam to C line the raw counts from DL17 + DL20 account for only 0.75 % of total counts. Even if these are attenuated by a factor of 10 they contribute only 7.5 % to the total signal. For the case of all the beam to D line, DL17 + DL20 account for 49 % of the total. If they are attenuated by a factor of 10 then ~10 % of the signal is due to all other monitors, and these two account for 90 % of the signal. If we use the calibrations for C-only to derive the amount of beam lost in RNSW and the portion of SWCV not including DL17 and DL20, then the amount of beam lost in these areas, for the case in which the D-only loss is 2.407, is 0.658 TP. Using a constant of 8.70e-7 TP/count for the DCV loss (see below), then the total amount lost on DL17 and DL20 becomes 1.365 TP. Therefore approximately 69 % of the beam lost in SWCV is being seen only by DL17 and DL20. Certainly this isn't definitive, but it seems to be a crucial area that should be studied.

Table V shows the constants derived from the data in table IV. The values are consistant with those in table III. Some attempt is made to extract a seperate constant for the DL17 and DL20 loss monitors. The C_{CV} and C_{DV} values are much different than those in table III. This is because the data in table II includes a subtraction of a short loss monitor under the targets which is not included in the data in table IV.

Table V. Calibrations based on raw long loss monitor data. (units are TP/count)

Constant	C On T	C Off T	D only	D DL17&20*	D w/ 2/3 SWCV
C_{RN}	5.33e-6	7.40e-6	5.56e-6	5.75e-6	5.56e-6
C_{SW}	1.94e-6	8.75e-6	19.6e-6	44.8e-6	29.4e-6
C_{CDV}	0.0041e-6	0.698e-6	0.87e-6	0.454e-6	0.87e-6

* based on using only the sum of DL17 and DL20 as SWCV

Using the constants derived above to estimate the transport efficiencies for split beams may seem like a leap in faith which, perhaps, we really shouldn't have. Nevertheless, Table VI shows what the efficiencies would be if we did have this faith. The data for RNSW, SWCV, and the caves is based on the CLYDE values for those numbers, rendered 'raw' in the same manner as in table II. What is called 'loss' is the amount of beam in TP lost (Δ SEC), based on summing the losses per equation (1). T/I and LLS are the numbers as reported by CLYDE. The calibrations used are for those with beam on target per table III. The value used for SWCV is based on a combination of that for C-only and that for D-only, depending on the fraction of beam going to D-line over the total amount of beam. In summery, the actual numbers used were $C_{RN} = 5 \times 10^{-6}$, $C_{SW} = 13 \times 10^{-6}$ x DSEC/(sum of SEC's) + 2.3×10^{-6} x fraction remaining, $C_{CV} = 0.33 \times 10^{-6}$, $C_{DV} = 1.9 \times 10^{-6}$, and ACV and BCV were taken as 1.1×10^{-6}.

Table VI. Losses based on above calibrations.

LBM*	RNSW	SWCV	ACV/10	BCV	CCV	DCV	loss**	%loss***	(1-T/I)	LLS
1.34	29718	102526	4305	0	6269	4087	0.494	40.9	-7.5	46.9
7.76	88606	220839	16068	0	27910	129794	2.089	30.8	6.3	22.8
11.16	142489	175275	4792	0	16393	123155	1.739	22.9	9.6	11.5
32.20	283744	592432	20475	14551	124723	169415	4.539	17.8	28.1	13.5
36.39	249955	603379	61617	2325	359237	196476	4.558	16.5	14.9	17.5

* actually LBM(1-ineff) ** based on sum of caves with above calibrations *** actually %loss + xineff.

The differences between CCV in the table may be an effect of the amount of beam on target (since some is split to go to C3), in which case the % loss is an over-estimate. Also the above equation is not exactly correct, since monitors near targets can be lit up by targeting. The actual relation is;

$$\Delta SEC = \sum_{n=1}^{m} l_n C_n - \sum_{k=1}^{t} s_k C_k$$

where s is the short loss monitors by the targets (t would typically equal 4).

Discussion:

The important lessons learned are the following:

1. The value the SEC's give depends on whether the beam is on or off target. This could be due to backscattering or simply due to placing the beam on a different spot on the SEC. Certainly there is something important here to study. For this report the value returned by the SEC with beam on target was used simply because this gave the most linear curve. Certainly it could be argued to use the result of beam off target since this would eliminate the error due to any backscattering. But, we don't run the program with beam off target, so this would make comparisons to normal running impossible. The calibration of the loss monitors depends on knowing how much beam actually gets to the SEC's, so the problem is an important one.

2. The calibrations of the long loss monitors are not at all the same, varying over factors as high as x10. To truly calibrate them would require dedicated study time, but it seems it is possible.

3. How much beam was actually being lost hasn't been answered, but a few things seem more apparent now. First the SEC's seem to vary by larger amounts than the loss monitors. Secondly it appears, based on Table VI that the LLS % displayed on CLYDE incorrectly estimates the amount of beam lost. To first order this may be simply due to erroneous values returned by the ACV and CCV losses, but there is also an intrinsic error due to incorrect calibrations on some loss monitors.

4. Figures VIII - IX show there are very definite areas of loss in the switchyard. The losses on the splitters and the lambertsons are unavoidable. Other loss points need to be evaluated to determine whether there may need to be a design change or if it was simply not the best tune. Points of concern are the CL22 - CL28 (CP2, BD4, & CD4) and CL37 (CQ10) losses for the C-only case, the DL20 (DD12 - DQ6), DL24 (air gap ?) and DL27 (DQ7), the DL33 (DD15) and DL39 (DQ8&9) losses for the D-only case. Finally there is the AL28 loss for the D-only case. This particular loss is annoying simply because there is no obvious explaination for it. Is a piece of beam being sent down A-line without lighting up the AL22 and AL24 monitors and not hit on the SEC ? Or is something in D-line getting hit so hard that the scattering gets through the shielding to light up the AL28 monitor ? One observation, from looking at the switchyard maps, is that the A-cave is very well shielded from the D-cave, but there is a trench connecting the two caves. The problem may also be a crack in the shielding, based on how the blocks are put together. Certainly the problem merits further study.

5. One final note; the losses in the B-cave appear to be wrong simply by looking at the raw values from the loss monitors. BL44 and BL46 have relatively large negative values when there is no beam in B-line (large negative offset ?), and the BCV reads near zero with only a small amount of beam in B. With larger amounts of beam in B the BCV value does not increase too greatly. Perhaps we are doing a fantastic job tuning B-line, on the other hand it has been noted that when more beam is put in B-line the sum of the target SEC's drops, making the total transport efficiency drop significantly. [3] This is another area which needs to be studied more carefully.

References:

1. p. 71, SEB Setup Book II FY94; data plotted by P. Pile.
2. p. 65, SEB Setup Book II FY94; data taken by JWG and JSL.
3. private conversation with P. Pile.

Definitions:

SEB	Calibrated value of CE010 displayed on CLYDE
CE010	Ion chamber in switchyard located 10 feet from F13 AGS straight section
LBM	AGS current transformer sampled just before extraction
PLS	Sum of point losses normalized and calibrated with subtraction included
LLS	Sum of RNSW, SWCV, ACV, BCV, CCV, and DCV
ACV	AL28L - AL304 (both normalized and calibrated) => "A Cave"
BCV	BL44L + BL46L - BL481 (normalized and calibrated) => "B Cave"
CCV	CL44L + CL47L - CL491 (normalized and calibrated) => "C Cave"
DCV	DL24+DL27+DL30+DL33+DL39 - DL401 (norm. and cal.) => "D Cave"
T/I	100 * (A+B+C+D)/LBM ; percentage of beam to targets
RNSW	CL03+CL06+CL09
SWCV	CL13+CL16+CL19+CL22+CL25+CL28+CL31+CL34+CL37+ CL39+AL22+AL24+DL17+DL20
XEFF	CE010/LBM ; extraction efficiency
XINEFF	(sum of 4 ags long loss monitors subtending entire ring)/LBM
A	A SEC
B	B SEC
C	C SEC
D	D SEC
CL##	long loss monitor located ##0 feet from F13.
SEC	secondary emission chamber - consists of two plates at some potential difference (typically 1000 - 2000 volts) and under vacuum, through which the beam passes
AION	AL304 x calibration constant {loss monitor under target, values calibrated to read in TP}
BION	BL481 x calibration constant "
CION	CL491 x calibration constant "
DION	DL401 x calibration constant "

Proposed Studies :

Hints of various studies to be done were made throughout the studies report. This section will outline a number of proposed studies based on the findings of this report. In general each study would include a set of data representing the state of SEB extraction. This set would include Orbits, IPM's and extraction efficiency data.

# shifts:		
1-2	0.	Test of EPM's as intensity monitors: This test consists of "calibrating" the vertical EPM (in front of CD2&3 and 1st EPM in D line) area for intensity and testing the linearity vs intensity. The ideal situation would be to test over a range of intensities from 1TP to 10 TP for linearity. As clean a transport as possible needs to be setup with unsplit beam. Extraction efficiency calibration should be done first.
1-2	1.	Tests of reproducability of calibrations. This study would test if the loss monitors around the splitters and lambertsons have the same calibration independent of which side of the septa the loss is generated from. We would use EPM's in D-line and the EPM in front of CD2&3 to measure relative intensities. All the beam would be transported down a single line, a scan of losses vs intensity would be done and then using the splitters and lambertsons the beam would be shifted all down another line and another scan would be done. Losses would be minimized in each case.
2-3	2.	Calibration of individual monitors. Carefully trying to lose all the beam (at low intensities) at specific points, measure the response of the loss monitors in that area. This would require a calibration of C10 and the extraction efficiency would be done first. Areas of priority would be monitors after AD2&3 (from placing the beam onto the septum), monitors around the D-line bend, and monitors around CP2.
1	3.	Source of ACV loss with all beam in D-line. This is basically a search for possible sources of this loss. It would require the help of HP.
1	4.	What is the B-line/B-cave efficiency. Put all the beam in B and reproduce the kind of data taken for this report. Certainly prior to the study a careful review of the state of the instrumentation would be done. Also, what is called the B-cave loss should be made to reflect transport to B5.
1-2	5.	Transport efficiency of D, C, and A lines. Put all the beam down each line and scan losses versus intensity, all beam on targets for each case. EPMs will be used as intermediate intensity monitors.
1	6.	Test of measured intensity vs postion of beam on SEC's: The goal of this study would be to try to determine whether the SEC response is sensitive to hitting the target or is due to where the SEC foil is being hit. It is possible we may want to remove one of targets during the study.

Total = 8 - 12 shifts.

TABLE VII: CLYDE DATA SETS

	Condition	SEB	LBM	XEFF	XINEFF	LLS	T/I	A	B	C	D	RNSW	SWCV	ACV	BCV	CCV	DCV	PLS
10 MAY	ABCD	1.23	1.4	87.73	4.04	46.9	107.5	0.16	1.01	0.2	0.13	7.49	25.84	10.85	-0.1	1.58	1.03	36.8
10 MAY	ABCD	8.4	8.08	104	3.94	22.8	93.67	0.97	0.18	3.62	2.75	3.27	8.15	5.93	-0.1	1.03	4.79	23.9
10 MAY	ABCD	13.03	12.04	107.2	7.34	11.5	90.41	0.61	0.28	6.54	1.88	3.39	4.17	1.14	-0.08	0.39	2.93	15.7
17 JUL	ABCD	32.22	33.44	96.38	3.71	13.5	71.94	5.49	4.15	9.36	5.17	2.73	5.7	1.97	0.14	1.2	1.63	12.3
17 JUL	ABCD	36.04	37.91	95.04	4	17.5	85.08	2.44	6.3	16.67	6.77	2.15	5.19	5.3	0.02	3.09	1.69	15.4
		JWG/JSL DATA																
30 JUN	COFF T	8.09	8.77	92.28	2.37	6.6	87.26	0.01	0.03	7.61	0	1.6	3.98	0.09	-0.13	1.02	0.04	3.9
30 JUN	COFF T	8.25	8.91	92.6	2.38	7.2	88.5	0.01	0.04	7.83	0	1.49	4.28	0.09	-0.12	1.4	0.03	3.9
30 JUN	CON T	14.62	15.83	92.33	2.26	7.2	93.34	0.01	0.04	14.73	0	1.57	3.99	0.05	-0.07	1.63	0.03	2.9
30 JUN	A/D OFF T	8	8.65	92.49	2.49	8	69.41	2.24	0.01	0.03	3.69	1.81	2.38	0.99	-0.14	0.17	2.89	7.9
30 JUN	B ON T	7.64	8.26	92.44	2.38	10.6	102.2	0.01	8.43	0	0.01	1.28	7.16	0.09	1.84	0.17	0.06	6.5
30 JUN	B ON T	14.15	15.32	92.36	2.28	10.4	101.6	0.01	15.54	0	0	1.26	7.02	0.05	1.92	0.1	0.02	6
30 JUN	D OFF T	6.54	7.1	92.24	2.66	15.4	92.66	0.05	0	0.02	6.35	2.5	1.49	0.53	-0.16	0.18	9.9	13.4
30 JUN	D ON T	12.83	13.89	92.42	2.37	14.7	80.35	0.11	0.01	0.02	11.29	2.21	1.54	0.56	-0.07	0.09	10.42	16.2
30 JUN	D ON T	14.34	15.54	92.31	2.36	14.3	80.39	0.12	0.01	0.02	12.3	2.2	1.5	0.54	-0.06	0.08	10.81	15.5
30 JUN	D OFF T	14.49	15.71	92.21	2.36	14.5	92.9	0.13	0.01	0.02	14.64	2.21	1.59	0.59	-0.06	0.08	10.12	13.2
30 JUN	CON T	8.07	7.88	92.36	2.38	10.9	93.7	0.01	0.03	8.13	0.01	1.54	4.14	0.1	-0.12	5.23	0.04	3.2
30 JUN	CON T	8.14	8.82	92.29	2.39	10.6	93.6	0.01	0.03	8.22	0	1.58	4.01	0.09	-0.13	4.96	0.05	3.1

		CL03	CL06	CL09	CL13	CL16	CL19	CL22	CL25	CL28	CL31	CL34	CL37	CL39	AL22	AL24	DL17	DL20
30 JUN	COFF T	0.23	0.32	1.06	0.06	0.1	0.16	0.56	0.94	0.95	0.15	0.06	0.79	0.05	0.06	0.09	0.02	0.01
30 JUN	COFF T	0.23	0.29	0.97	0.06	0.11	0.19	0.68	1.08	0.96	0.14	0.06	0.74	0.04	0.08	0.11	0.02	0.01
30 JUN	CON T	0.22	0.3	1.05	0.05	0.09	0.16	0.57	0.95	0.96	0.14	0.06	0.79	0.05	0.06	0.09	0.02	0.01
30 JUN	A/D OFF T	0.26	0.39	1.16	0.23	0.28	0.29	0.28	0.17	0.09	0.01	0.01	0.09	0	0.13	0.4	0.16	0.25
30 JUN	B ON T	0.23	0.27	0.78	0.04	0.06	0.12	0.99	1.48	1.31	0.22	0.33	2.3	0.07	0.08	0.13	0.02	0.01
30 JUN	B ON T	0.22	0.27	0.77	0.03	0.06	0.11	0.93	1.43	1.3	0.22	0.33	2.31	0.07	0.07	0.12	0.01	0.01
30 JUN	D OFF T	0.28	0.76	1.46	0.1	0.24	0.09	0.06	0.07	0.05	0.01	0.01	0.07	0	0.03	0.03	0.14	0.59
30 JUN	D ON T	0.24	0.61	1.36	0.1	0.22	0.09	0.07	0.08	0.05	0.01	0.01	0.08	0	0.03	0.04	0.13	0.63
30 JUN	D ON T	0.24	0.61	1.34	0.1	0.22	0.09	0.07	0.07	0.05	0.01	0.01	0.08	0	0.03	0.4	0.12	0.62
30 JUN	D OFF T	0.24	0.59	1.38	0.1	0.22	0.09	0.08	0.08	0.06	0.01	0.01	0.09	0	0.03	0.04	0.12	0.65
30 JUN	CON T	0.23	0.3	1.01	0.6	0.1	0.18	0.63	1.02	0.95	0.14	0.06	0.75	0.05	0.07	0.1	0.02	0.01
30 JUN	CON T	0.23	0.31	1.04	0.6	0.1	0.16	0.58	0.96	0.95	0.15	0.06	0.77	0.05	0.06	0.09	0.02	0.01

		AL28	BL44	BL46	CL44	CL47	DL24	DL27	DL30	DL33	DL39	AION	BION	CION	DION
30 JUN	COFF T	0.09	-0.11	-0.06	0.32	1.1	0.01	0	0	0.01	0.01	0	-0.1	0.4	0
30 JUN	COFF T	0.09	-0.1	-0.06	0.5	1.75	0.02	0	0	0	0.01	0	-0.1	0.8	0
30 JUN	CON T	0.05	-0.06	-0.03	2.33	4.34	0.01	0	0	0	0.01	0	-0.1	5	0
30 JUN	A/D OFF T	1	-0.11	-0.06	0.06	0.14	1.33	0.17	0.03	0.53	0.74	0	-0.1	0	0
30 JUN	B ON T	0.09	0.17	0.34	0.06	0.15	0.02	0.01	0.01	0	0.01	0	0.2	0	0
30 JUN	B ON T	0.05	0.22	0.37	0.03	0.09	0.01	0	0	0	0.01	0	0.2	0	0
30 JUN	D OFF T	0.53	-0.13	-0.08	0.07	0.16	6.13	0.82	0.08	1.57	2.31	0	-0.1	0	0
30 JUN	D ON T	0.56	-0.06	-0.04	0.03	0.08	4.88	1.09	0.15	1.77	2.66	0	-0.1	0	0.2
30 JUN	D ON T	0.54	-0.06	-0.03	0.03	0.07	4.37	1.14	0.13	1.8	2.73	0	-0.1	0	0.2
30 JUN	D OFF T	0.6	-0.06	-0.03	0.03	0.07	4.32	1.16	0.09	1.78	2.75	0	-0.1	0	0
30 JUN	CON T	0.1	-0.11	-0.06	2.27	7.87	0.02	0	0	0	0.02	0	-0.1	4.9	0
30 JUN	CON T	0.09	-0.11	-0.06	2.37	7.8	0.01	0.01	0.01	0.01	0.02	0	-0.1	5.2	0

TABLE VIII: "RAW" & UNNORMALIZED DATA SETS

	Condition	SEB	LBM	XEFF	XINEFF	LLS	T/I	A	B	C	D	RNSW	SWCV	ACV	BCV	CCV	DCV	PLS
10 MAY	ABCD	963.6	97.7	87.73	4.04	185254	25.16	288.3	1576	359.7	234	29718	1E+05	43050	-397	6269	4087	36.8
10 MAY	ABCD	6580	563.9	104	3.94	625123	23.92	1748	280.8	6511	4950	88606	2E+05	2E+05	-2710	27910	1E+05	23.9
10 MAY	ABCD	10208	840.2	107.2	7.34	501865	19.86	1099	436.8	11763	3384	1E+05	2E+05	47917	-3363	16393	1E+05	15.7
17 JUL	ABCD	24354	1032	96.38	3.71	1389617	41.03	9615	7268	16392	9054	3E+05	6E+05	2E+05	14551	1E+05	2E+05	12.3
17 JUL	ABCD	27241	1170	95.04	4	2027541	48.19	4273	11033	29194	11856	2E+05	6E+05	6E+05	2325	4E+05	2E+05	15.4
	JWG/JSL DATA																	
30 JUN	C OFF T	6338	270.6	92.28	2.37	172239	50.83	18.02	46.8	13687	0	41755	1E+05	2349	-3393	26619	1044	3.9
30 JUN	C OFF T	6463	274.9	92.6	2.38	190815	51.52	18.02	62.4	14083	0	39653	1E+05	2395	-3194	37258	798.4	3.9
30 JUN	C ON T	11453	488.4	92.33	2.26	339561	54.41	18.02	62.4	26493	0	74043	2E+05	2358	-3301	76873	1415	2.9
30 JUN	A/D OFF T	6267	266.9	92.49	2.49	209032	40.27	4036	15.6	53.96	6641	46710	61419	25548	-3613	4387	74581	7.9
30 JUN	B ON T	5985	254.8	92.44	2.38	261239	51.75	18.02	13151	0	18	31546	2E+05	2218	45347	4190	1479	6.5
30 JUN	B ON T	11085	472.6	92.36	2.28	473340	51.33	18.02	24243	0	0	57513	3E+05	2282	87639	4565	912.9	6
30 JUN	D OFF T	5123	219	92.24	2.66	304637	52.75	90.09	0	35.97	11429	52742	31434	11181	-3375	3797	2E+05	13.4
30 JUN	D ON T	10051	428.5	92.42	2.37	610460	48	198.2	15.6	35.97	20320	91465	63736	23177	-2897	3725	4E+05	16.2
30 JUN	D ON T	11234	479.4	92.31	2.36	697109	46.74	216.2	15.6	35.97	22138	1E+05	69387	24979	-2775	3701	5E+05	15.5
30 JUN	D OFF T	11351	484.7	92.21	2.36	679160	54.96	234.2	15.6	35.97	26350	1E+05	74320	27578	-2805	3739	5E+05	13.2
30 JUN	C ON T	6322	243.1	92.36	2.38	284533	60.49	18.02	46.8	14622	18	40090	1E+05	2603	-3124	1E+05	1041	3.2
30 JUN	C ON T	6377	272.1	92.29	2.39	277285	54.57	18.02	46.8	14784	0	41488	1E+05	2363	-3414	1E+05	1313	3.1

	CL03	CL06	CL09	CL13	CL16	CL19	CL22	CL25	CL28	CL31	CL34	CL37	CL39	AL22	AL24	DL17	DL20
C OFF T	6002	8351	27663	1566	2609.7	4175	14614	24531	24792	3915	1566	20616	1305	1566	2349	521.9	261
C OFF T	6121	7718	25815	1597	2927.4	5056	18097	28742	25548	3726	1597	19694	1065	2129	2927	532.3	266.1
C ON T	10375	14148	49519	2358	4244.5	7546	26882	44803	45275	6603	2830	37257	2358	2830	4245	943.2	471.6
A/D OFF T	6710	10065	29935	5935	7225.8	7484	7226	4387	2323	258.1	258.1	2323	0	3355	10323	4129	6452
B ON T	5668	6654	19223	985.8	1478.7	2957	24399	36475	32285	5422	8133	56684	1725	1972	3204	492.9	246.5
B ON T	10042	12324	35147	1369	2738.7	5021	42450	65273	59339	10042	15063	1E+05	3195	3195	5477	456.5	456.5
D OFF T	5907	16034	30801	2110	5063.2	1899	1266	1477	1055	211	211	1477	0	632.9	632.9	2954	12447
D ON T	9933	25246	56286	4139	9105.2	3725	2897	3311	2069	413.9	413.9	3311	0	1242	1655	5380	26074
D ON T	11102	28217	61986	4626	10177	4163	3238	3238	2313	462.6	462.6	3701	0	1388	18503	5551	28680
D OFF T	11218	27578	64504	4674	10283	4207	3739	3739	2805	467.4	467.4	4207	0	1402	1870	5609	30382
C ON T	5987	7810	26293	15619	2603.2	4686	16400	26553	24731	3645	1562	19524	1302	1822	2603	520.6	260.3
C ON T	6039	8140	27308	15755	2625.8	4201	15230	25208	24945	3939	1575	20219	1313	1575	2363	525.2	262.6

	AL28	BL44	BL46	CL44	CL47	DL24	DL27	DL30	DL33	DL39	AION	BION	CION	DION
C OFF T	2349	-2871	-1566	8351	28706	261	0	0	261	261	0	-500	1111	0
C OFF T	2395	-2661	-1597	13306	46573	532.3	0	0	0	266.1	0	-500	2222	0
C ON T	2358	-2830	-1415	1E+05	204680	471.6	0	0	0	471.6	0	-500	13889	0
A/D OFF T	25806	-2839	-1548	1548	3612.9	34323	4387	774.2	13677	19097	0	-500	0	0
B ON T	2218	4190	8379	1479	3696.8	492.9	246.5	246.5	0	246.5	0	1000	0	0
B ON T	2282	10042	16889	1369	4108.1	456.5	0	0	0	456.5	0	1000	0	0
D OFF T	11181	-2743	-1688	1477	3375.5	1E+05	17299	1688	33122	48734	0	-500	0	0
D ON T	23177	-2483	-1655	1242	3311	2E+05	45112	6208	73255	1E+05	0	-500	0	20000
D ON T	24979	-2775	-1388	1388	3238.1	2E+05	52734	6014	83265	1E+05	0	-500	0	20000
D OFF T	28045	-2805	-1402	1402	3271.9	2E+05	54221	4207	83201	1E+05	0	-500	0	0
C ON T	2603	-2864	-1562	59093	204874	520.6	0	0	0	520.6	0	-500	13611	0
C ON T	2363	-2888	-1575	62232	204813	262.6	262.6	262.6	262.6	525.2	0	-500	14444	0

TABLE IX: CLYDE CONSTANTS

Constants:		10 MAY	30 JUN	17 JUL
ASEC	=	5.55E-04	5.55E-04	5.71E-04
B5SEC	=	5.46E-04	5.46E-04	5.46E-04
BSEC	=	6.41E-04	6.41E-04	5.71E-04
C3SEC	=	5.60E-04	5.60E-04	5.60E-04
CBM	=	1.43E-02	3.24E-02	3.24E-02
CE01	=	1.28E-03	1.28E-03	1.32E-03
CSEC	=	5.56E-04	5.56E-04	5.71E-04
DSEC	=	5.56E-04	5.56E-04	5.71E-04
F5LM	=	3.96E-04	3.96E-04	3.96E-04
F10LM	=	1.45E-04	1.45E-04	1.45E-04
RLM	=	1.12E-03	1.12E-03	1.12E-03
LONGS	=	3.10E-04	3.10E-04	3.10E-04
SHORTS	=	2.00E-04	2.00E-04	2.00E-04
AL22L	=	3.70E-04	3.70E-04	3.70E-04
AL305	=	2.00E-04	2.00E-04	2.00E-04
AL28L	=	3.10E-04	3.10E-04	3.10E-04
CL482	=	3.60E-04	3.60E-04	3.60E-04
DL401	=	1.00E-05	1.00E-05	1.00E-05
DL24L	=	3.10E-04	3.10E-04	3.10E-04

FIGURE I: CE010 vs EXTRACTED BEAM INTENSITY

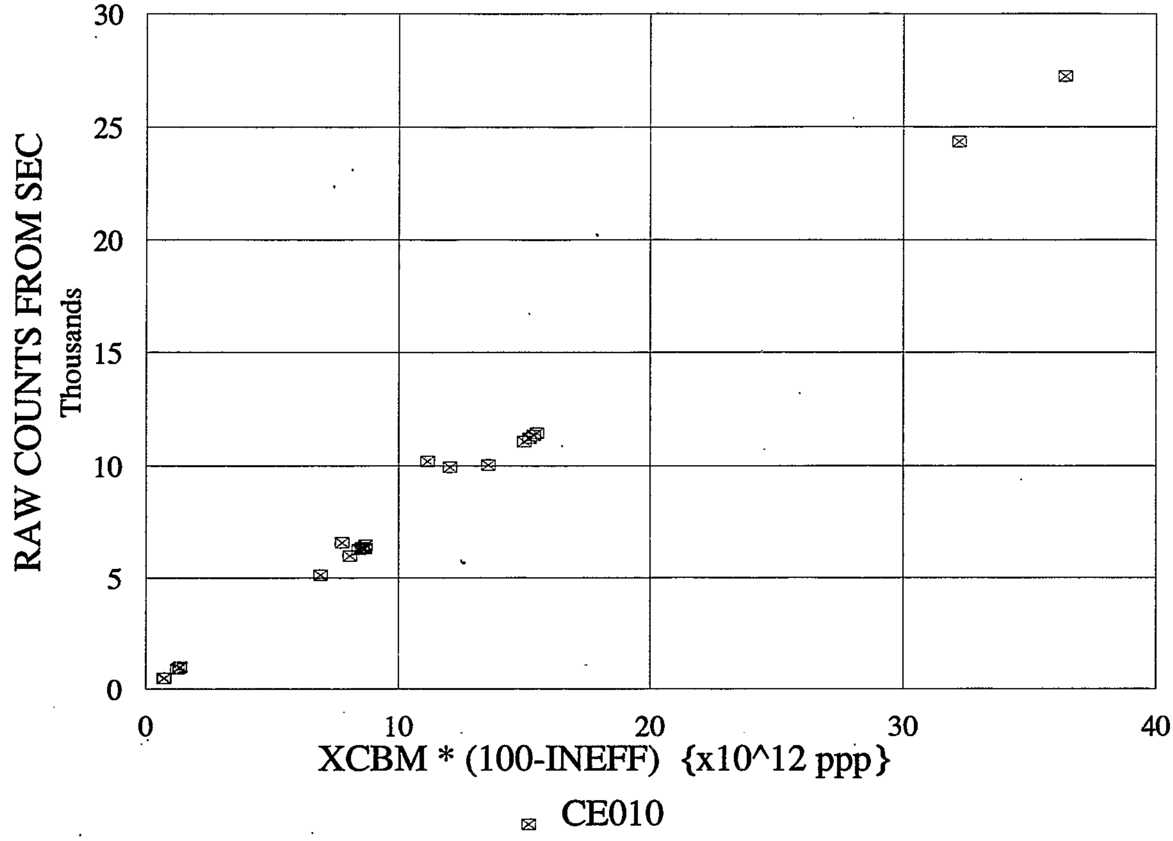

FIGURE II: CSEC vs EXTRACTED BEAM INTENSITY

ALL BEAM TO C LINE

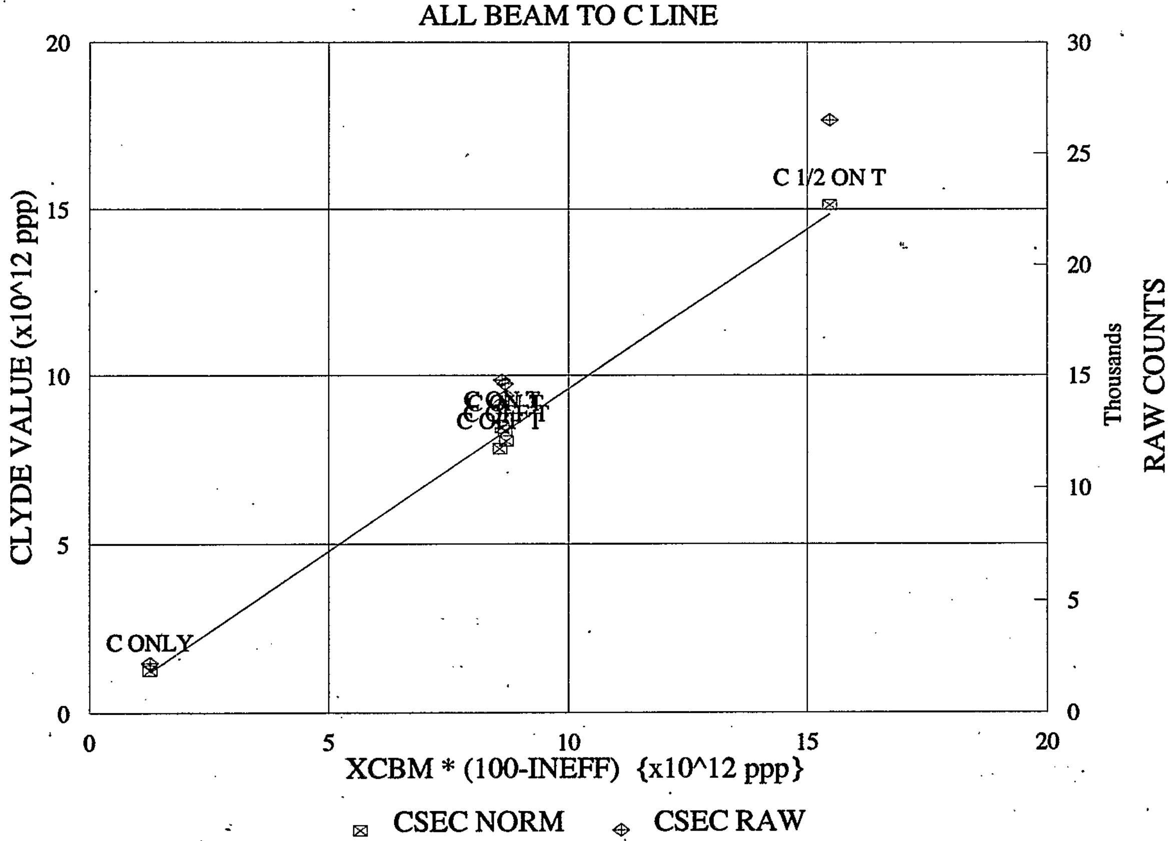

FIGURE III: DSEC vs EXTRACTED BEAM INTENSITY

ALL BEAM TO D ONLY

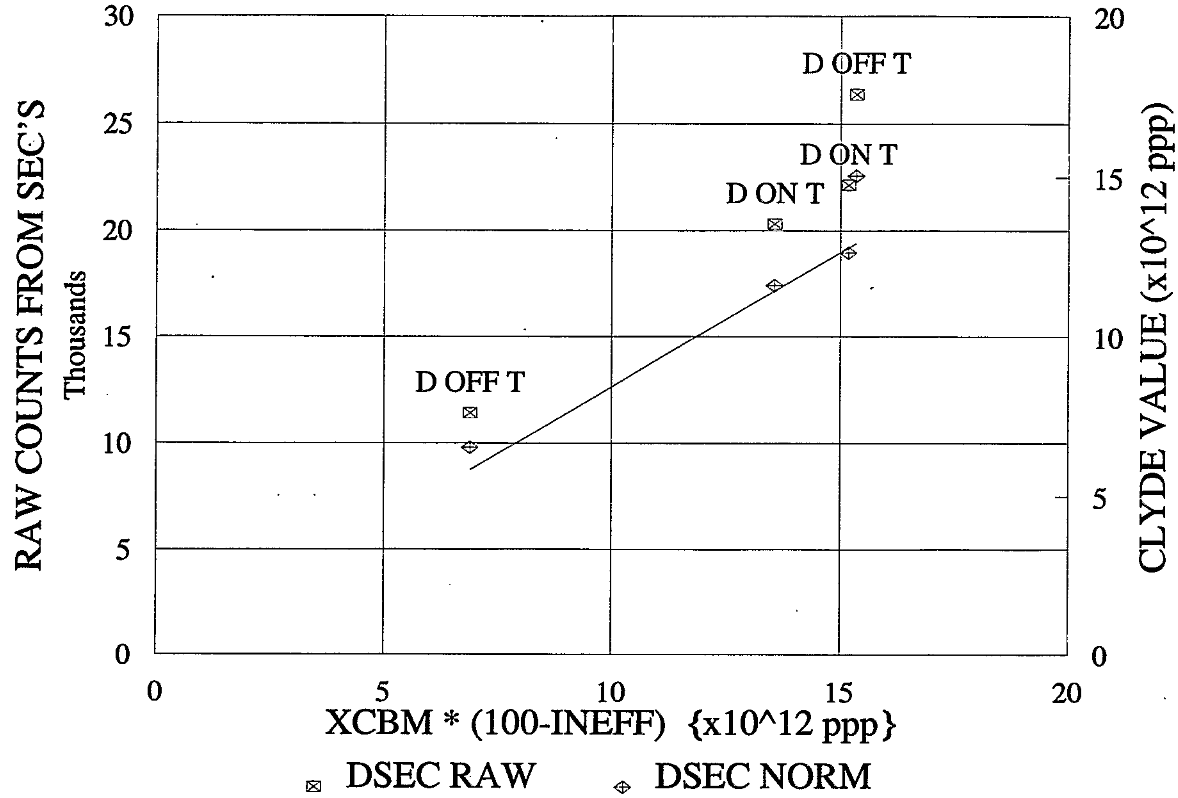

FIGURE IV: SWITCHYARD LOSSES vs AMOUNT OF BEAM LOST

BEAM TO C ONLY

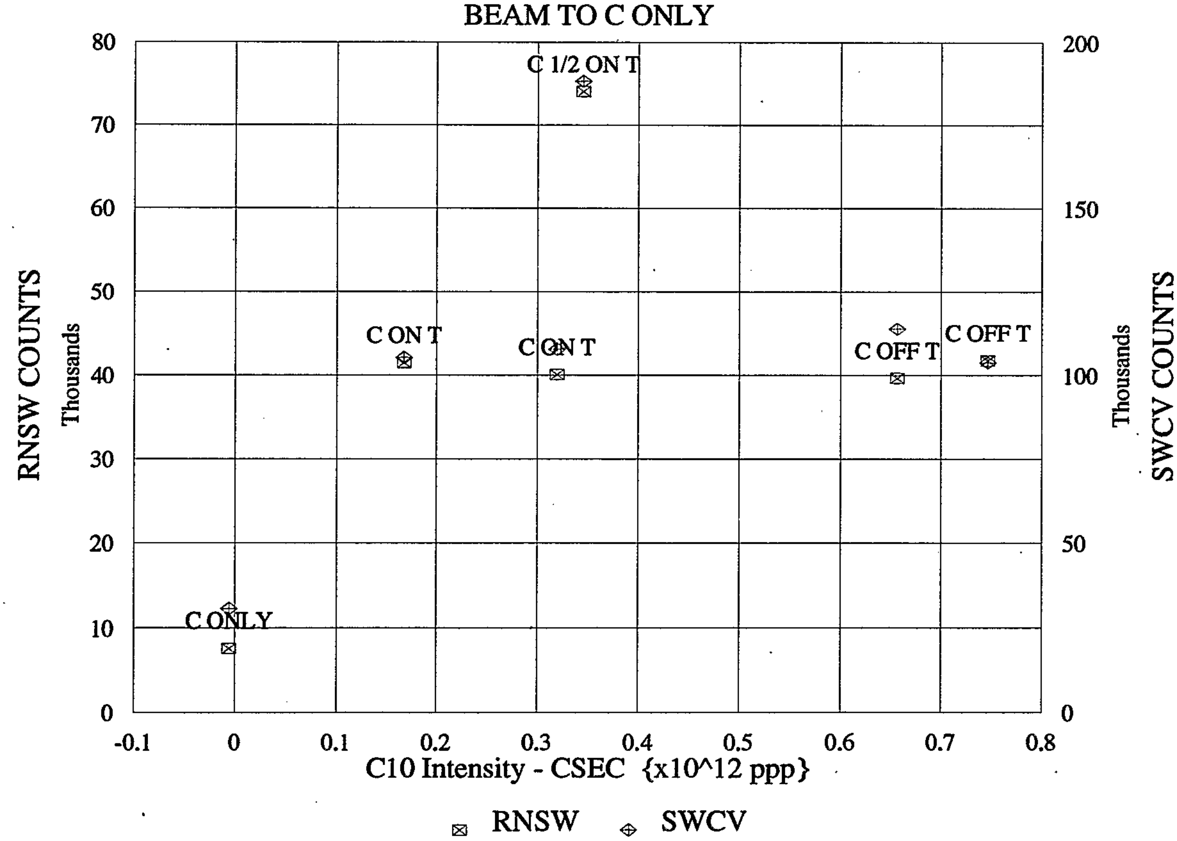

FIGURE V: SWITCHYARD LOSSES vs AMOUNT OF BEAM LOST

BEAM TO D ONLY

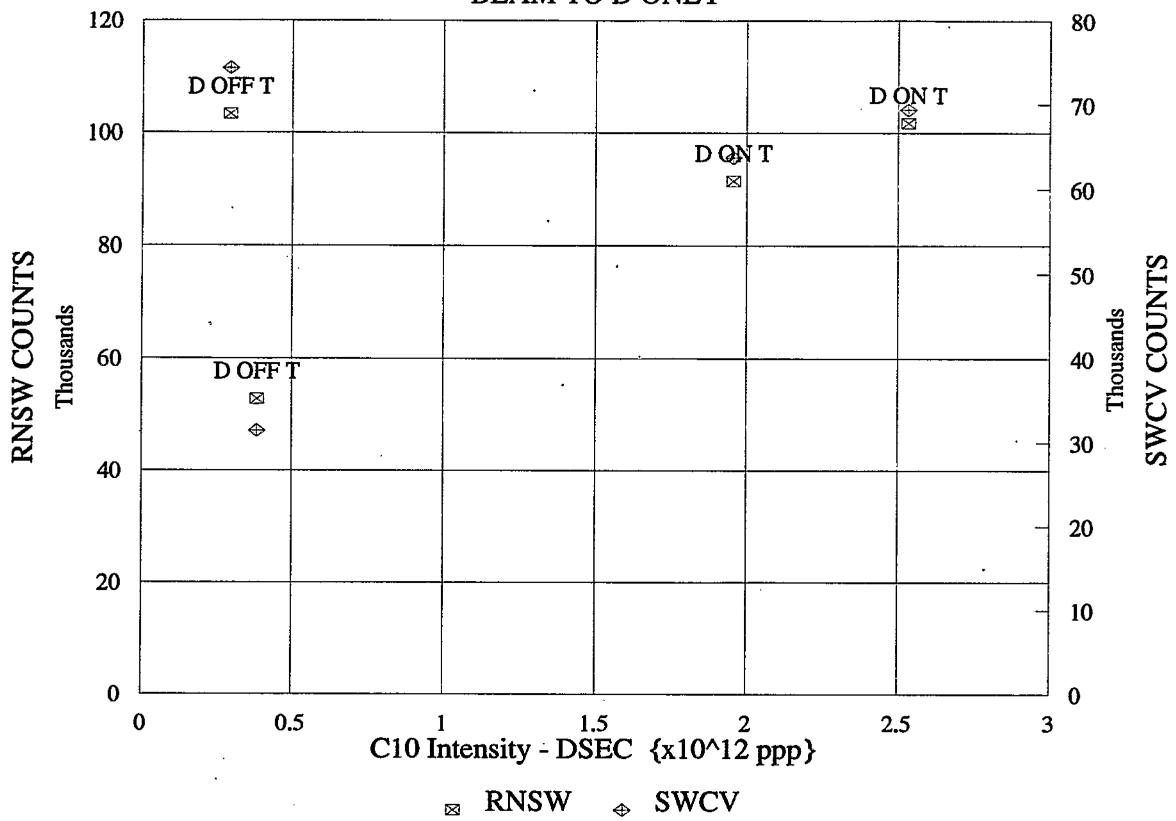

FIGURE VI: LONG LOSSES vs AMOUNT OF BEAM LOST

FOR CONSTANT TRANSPORT EFFICIENCY, BEAM TO C ONLY

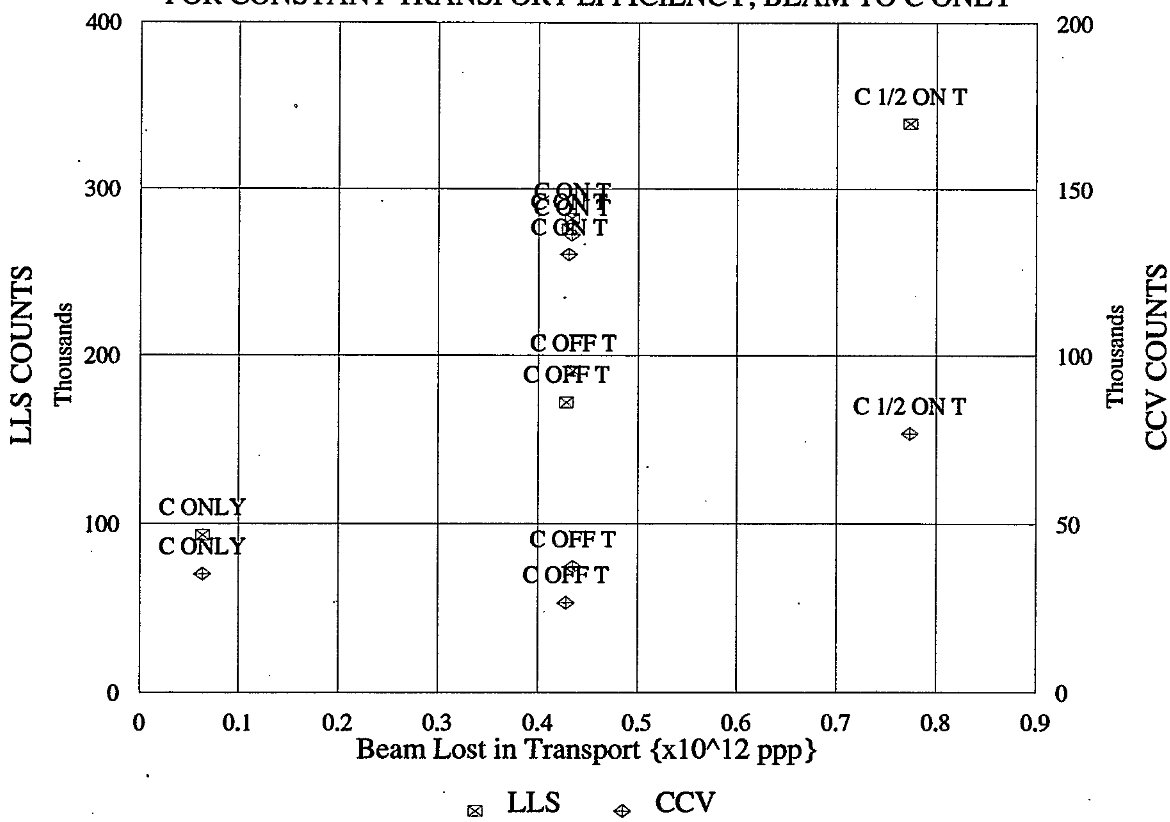

FIGURE VII: LONG LOSSES vs AMOUNT OF BEAM LOST

FOR CONSTANT TRANSPORT EFFICIENCY, BEAM TO D ONLY

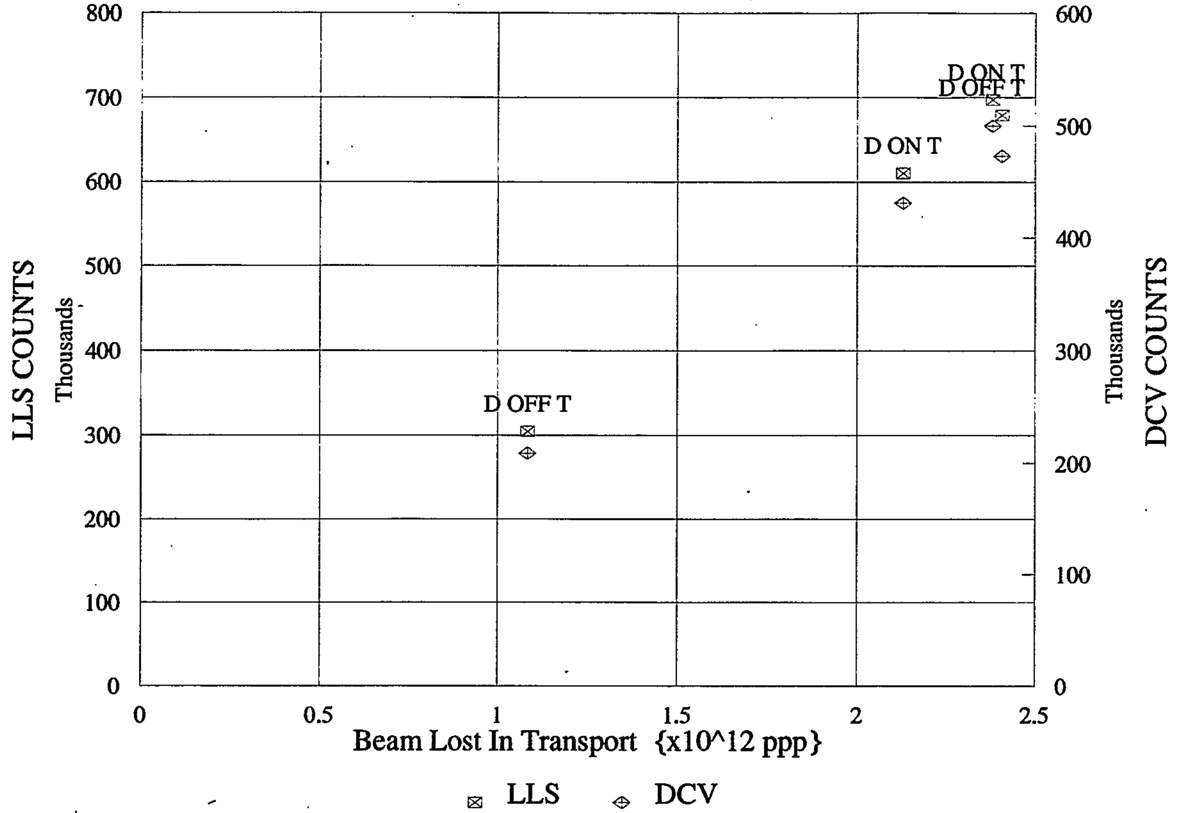

FIGURE VIII: LONG LOSSES vs LOCATION IN BEAM LINES

BEAM TO C ONLY

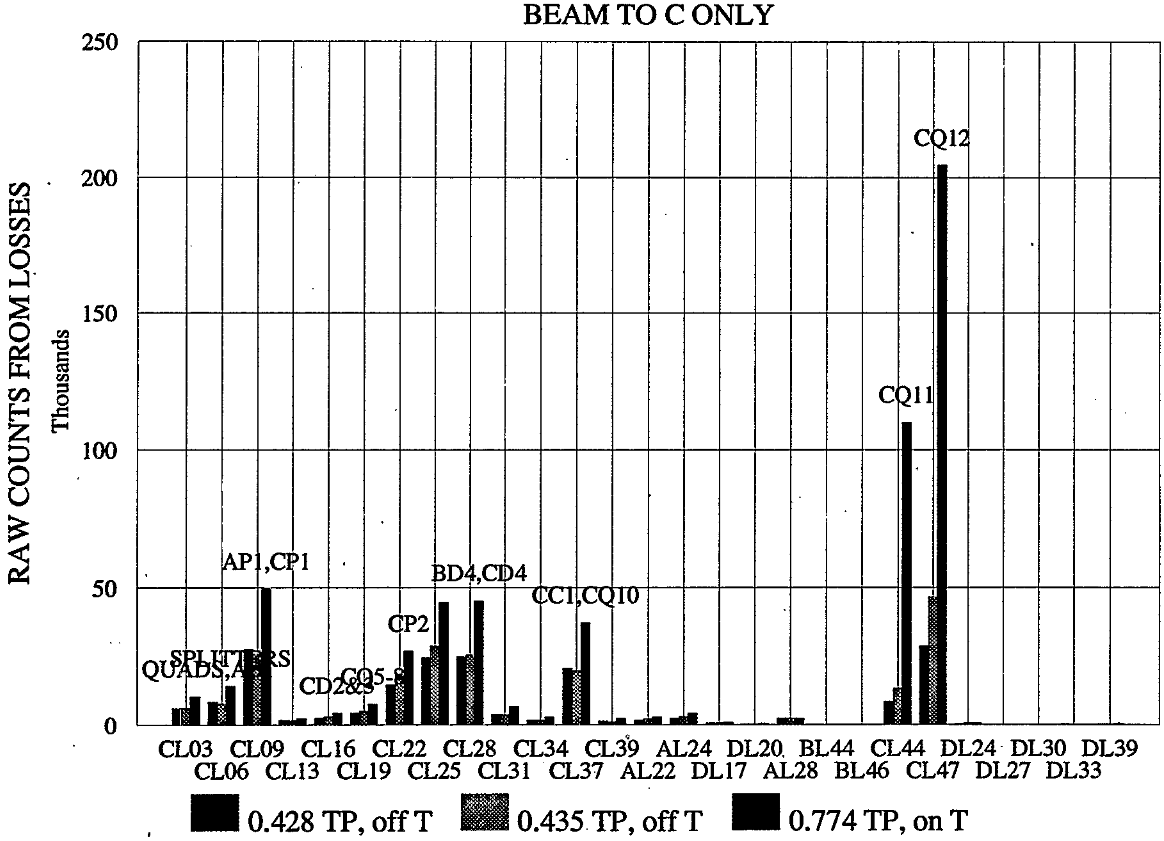

FIGURE IX: LONG LOSSES vs LOCATION IN BEAM LINES