The Parameter Spreadsheets and Their Applications

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Abstract

This paper is to announce that a set of parameter spreadsheets, using the Microsoft EXCEL software, has been developed for the SSC (and also for the LHC). In this program, the input (or control) parameters and the derived parameters are linked by equations that express the accelerator physics involved. A subgroup of parameters that are considered critical, or possible bottlenecks, has been highlighted under the category of "Flags". Given certain performance goals, one can use this program to "tune" the input parameters in such a way that the flagged parameters not exceed their acceptable range. During the past years, this program has been employed for the following purposes: a) To guide the machine designs for various operation scenarios, b) To generate a parameter list that is self-consistent and, c) To study the impact of some proposed parameter changes (e.g., different choices of the rf frequency and bunch spacing).

I. INTRODUCTION

The Superconducting Super Collider (SSC) consists of a linac and four synchrotrons (three boosters and a collider). There are a great number of machine and beam parameters that need to be adjusted in a coordinated manner in order to reach the specified goals of performance. For this purpose, a set of EXCEL spreadsheets, the Spreadsheets of SSC Parameters (SSP), has been developed as an integrated design tool to tune the machines.

In this program, there are two categories of parameters — the input (or control) parameters and the derived parameters. All are linked by equations that express the accelerator physics involved. A subgroup of derived parameters that are considered critical, or possible bottlenecks, has been highlighted under the category of "Flags". Critical levels have been assigned to each of the flagged parameters. The object of the game, given certain performance goals (usually luminosity and beam energy at collision), is to "tune" the input parameters in such a way that the flagged parameters not exceed their acceptable ranges.

A number of cases have been studied using SSP, including different operation scenarios and the choice of some important beam parameters such as the rf frequency and bunch spacing. A by-product of the program is the generation of the SSC Parameter List, which is now widely used in the laboratory as a quick design reference.

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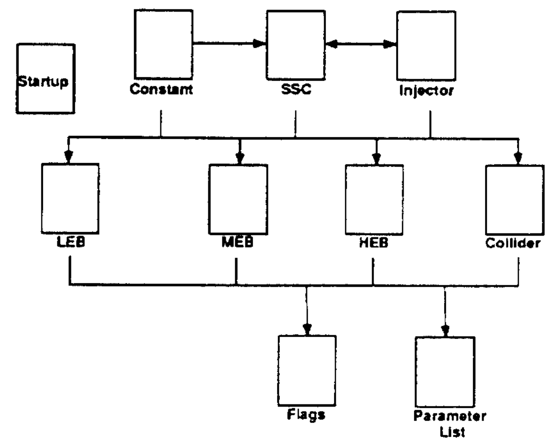

Figure 1. The worksheets in the SSP program.

II. THE SSP PROGRAM

The SSP program is in the form of 10 linked spreadsheets, using the Microsoft EXCEL software as shown in Figure 1. At present it contains about 100 input, 280 derived, and 35 flagged parameters, linked to each other by about 160 equations.

1. The spreadsheets:
   Top-level parameters are in the "SSC" worksheet, which appears as a "window" on the computer screen. Overall injector parameters are in the "Injector" worksheet. Specific machine parameters are generally listed in the corresponding worksheets. There is also a worksheet that contains all the physical constants used by the program. The "Flags" worksheet is set up to monitor the values of critical parameters. There are a total of 35 flagged parameters at this moment as listed in Table 1. Values in column B within safe operating ranges are indicated in column D with a "Green" flag; those outside acceptable ranges are flagged "Red". "Yellow" is used to indicate values near expected performance limits, which are described in Columns E and F. The macro-sheet, "Startup", can be used to open all the worksheets.

2. The input parameters:
   The input parameters are entered individually in the various worksheets. All are possible tuning "knobs",

Table 1. The Flags worksheet (nominal case)

	A	B	C	D	E	F
1	**Tune shift/spread:**					
2	Total Head-on Tune Shift	0.0038		Green	0.01	0.02
3	Total Long-range Tune Shift	0.0067		Yellow	0.006	0.01
4	Total Long-range Tune Spread	0.0020		Green	0.006	0.01
5	Space Charge Tune Shift, LEB	0.383		Green	0.4	0.7
6	Spa/Image Charge Tune Shift, MEB	0.078		Green	0.2	0.4
7	**Power loss:**					
8	Synch Radiation	9.0	kW/beam	Green	11	22
9	Parasitic heating	1.26	kW/beam	Green	3	9
10	Refrigerator usage factor	1.01		Green	1.25	2.5
11	**Collective instabilities:**					
12	Z.long.thresh, collider	3.7	ohm	Green	0.68	0.34
13	Z.trans.thresh, collider	247.1	Mohm/m	Green	40	20
14	Z.long.thresh, HEB	1.4	ohm	Yellow	1.9	0.95
15	Z.trans.thresh, HEB	16.6	Mohm/m	Green	10	5
16	Z.long.thresh, MEB	22.7	ohm	Green	1.4	0.7
17	Z.trans.thresh, MEB	34.1	Mohm/m	Green	1.9	0.95
18	Z.long.thresh, LEB	27.7	ohm	Green	2	1
19	Z.trans.thresh, LEB	18.4	Mohm/m	Green	0.76	0.38
20	Res wall growth time, collider	106	turns	Green	50	20
21	**Dynamic aperture:**					
22	*Dyn aper, collider, Inj*	13	sigma	Green	10	6
23	*Dyn aper, collider, IR*	11	sigma	Green	10	7
24	*Dyn aper, HEB, Inj*	11	sigma	Green	10	6
25	**Energy depo./rad. damage:**					
26	Peak energy depo, IR quads	0.104	mW/g	Green	4	8
27	Rad damage lifetime, collider	15.2	yr	Green	5	2
28	**Lifetime:**					
29	*Intrabeam lifetime, horiz emit*	211.2	hr	Green	96	48
30	*Intrabeam lifetime, longi emit*	120.2	hr	Green	96	48
31	Bucket/beam ratio, collider, Inj	30.4		Green	12	6
32	Bucket/beam ratio, collider, Op	25.1		Green	12	6
33	Lum lifetime, beam-beam	78.0	hr	Green	48	24
34	Lum lifetime, Residual gas	1378	hr	Green	48	24
35	**Vacuum:**					
36	H2.monolayer.buildup.time	5.7	day	Yellow	8	4
37	Re-desorption.pressure.rise.time	4.1	day	Yellow	8	4
38	**Others:**					
39	Lum reduction, IR1	0.91		Green	0.85	0.7
40	Events per crossing	1.8		Green	3	30
41	HEB.Dwell	20.1	s	Green	30	60
42	Collider.Dwell	74.9	min	Green	80	160
43	Equatorial.pressure.quenching	18.8	psi	Green	200	300

but those commonly varied are the beam and performance input parameters as listed in Table 2, in which E is the beam energy, $\mathcal{L}$ the luminosity at one interaction point (IP), S_B the bunch spacing, ϵ_N the normalized rms transverse emittance, ϵ_L the rms longitudinal emittance, β^* the β-function at the IP, P_{linac} the momentum of the protons extracted from the linac and p the vacuum pressure. The machine and lattice input parameters have tended to be relatively fixed, so that there has been less incentive to vary them. The input parameters are distinguished in the worksheets by appearing in bold type.

3. The formulae:
Most of the formulae are familiar to accelerator physicists. Some of them are valid only for the SSC. These are either obtained from computer simulations (e.g., the dynamic apertures) or derived specifically for the SSC (e.g., the filling factor and the cycle times).

III. APPLICATIONS

A. *Operation Scenarios*

SSP has been used to study a number of cases. Among them are:

- Case A – Nominal;
- Case B – Commissioning;
- Case C – High luminosity, $\mathcal{L} = 10 \times 10^{33}$;
- Case D – High energy, $E = 23$ TeV.

The input parameters of each case are listed in Table 2. The results are not included here because of the lack of space. In general one sees that, when the input parameters vary, the color of some flagged parameters will change to red. This indicates specific care is needed in order to adjust their values such that the color will turn back to green or yellow.

Table 2. Input Parameters

Case	A	B	C†	D
E (TeV)	20	20	20	23
$\mathcal{L}$ (10^{33} cm^{-2}s^{-1})	1	0.4	10	1
S_B (m)	5	20	10	5
ϵ_N (π mm-mrad)	1	3	2	1
ϵ_L (π eV-s)	0.233	0.233	0.466	0.233
β^* (m)	0.5	1	0.5	0.5
P_{linac} (GeV/c)	1.219	1.219	1.7	1.219
p (10^{-8} Torr)	1	5	1	1

†In Case C, two medium luminosity IP's are turned off to avoid large beam-beam tune shifts.

B. *Parameter List*

An on-line parameter list has been generated by the SSP program. The advantage of maintaining the list in such a way is that it is self-consistent and easy to update. The parameter list is on the node SSCVX1.SSC.GOV. One can have access to the list through a computer network either inside or outside the laboratory, by typing *SSCLAB* as the username [1]. The parameter list serves as a quick reference guide and is consistent with the Level 3 Specifications of the machine designs.

C. *Impact of Parameter Changes*

In the parameter space, when one changes, the others will follow suit. The SSP program is useful for this kind of study. Here we present two examples.

1. The choice of the rf frequency:
   The program has investigated the impact of the rf frequency when it varies from 180 MHz to 480 MHz. It shows that the changes of most beam parameters are small [2]. It is thus concluded that the choice should be based on other factors, such as the beam transfer from the HEB to Collider, the cost, and market availability.

2. The bunch spacing:
   The baseline bunch spacing in the SSC is 5 meters, which is mainly determined by the requirement of the detectors. But a larger bunch spacing is advantageous to the luminosity. In order to accommodate the flexibility of different bunch spacings in the accelerator design, the program has been employed to study the impact on the beam parameters when the spacing is increased to a multiple of 5 meters, using either the bunch coalescing scheme or the rf chopping scheme [3]. The possible bottlenecks are identified immediately by the program and a follow-up study is now under way.

IV. DISCUSSION

1. SSP is easy to use. By clicking the mouse a few times, one may readily make a judgment on whether or not a proposed operation scenario or parameter change would work. But SSP is neither robust nor bug-free. Care must be taken before drawing conclusions.

2. The present list of the flags is by no means complete. More flags will be added to the future version when the necessary information becomes available (e.g., vacuum, coupled-bunch instabilities, transition crossing, etc.).

3. SSP is not written for optimization. In other words, the control parameters need to be adjusted manually rather than by a computer search. Implementation of a search procedure should be straightforward but may be premature at this time.

4. A similar program has been developed for the LHC and its injectors (PS Booster, PS and SPS).

V. REFERENCES

[1] T. Barts and W. Chou, "SSC Parameter List," SSCL internal technical note PMTN-073P (May 1993).

[2] W. Chou and G. Schaffer, "Comments on the Collider rf Cavity in the SSC," SSCL internal technical note PMTN-036C (January 1992).

[3] W. Chou, "Comments on Bunch Spacing in the SSC," SSCL internal technical note PMTN-0060P (March 1993).