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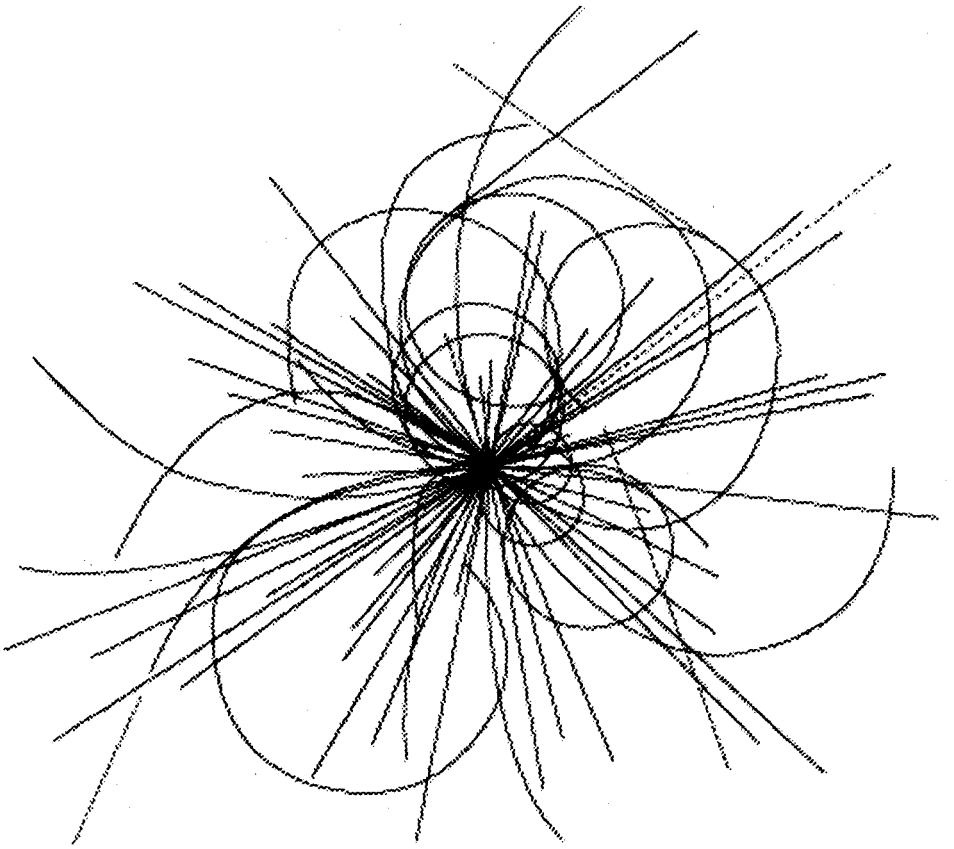

Superconducting Super Collider Laboratory

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SYNCH–STATUS AND RECENT USE AT SSCL*

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ABSTRACT

SYNCH is a computer program for use in the design and analysis of synchrotrons, storage rings, and beamlines. The first accelerator program to organize its input in the form of a language, **SYNCH** provides a natural way to describe and design lattices and to analyze them through calculations of betatron functions, dispersion, beam envelopes, emittances, and closed orbits. In addition, particle tracking, non-linear transformations, misalignments, electron integrals, and orbit corrections may be treated.

A brief summary of some features of the program and recent applications for designing the Interaction Regions (IR) of the SSC will given.

INTRODUCTION

The **SYNCH** program was first used in 1964-5 for the 200 BeV Design Study, and at present is programmed in FORTRAN 77.[1] The CMS code management system[2] is used to generate equivalent versions for different platforms. The latest version incorporates the ANSI/ISO GKS standard[3] for plotting and currently executes on VAX/VMS systems and Sun/UNIX Workstations with Sun GKS. A new Users Guide[4] will be available this year.

A table from the Users Guide summarizing commands available in **SYNCH** is included, as well as a discussion of how **SYNCH** has been used in recent design work for the Interaction Region (IR) of the Superconducting Super Collider (SSC).

CALCULATIONS PERFORMED BY SYNCH

The **SYNCH** program is used for the design and analysis of circular accelerators and beamlines. The program uses input commands to describe a lattice for the structure being studied. This lattice consists of basic elements such as drift spaces, dipole, quadrupole and sextupole magnets, and other non-linear elements. These elements are combined in beamline descriptions which can be manipulated to build up realistic accelerator lattices composed of thousands of elements.

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Having described the lattice, one can choose from nine types of calculations as follows:

- Matrix Definition and Operations: Beamline elements are represented by linear transfer matrices. Matrices representing sequences of elements in beamlines are obtained by matrix multiplication, reflection and other operations.
- Betatron Function Calculations: The linear betatron functions describe the amplitude and phase of the transverse betatron oscillations. The program calculates their values for all points in the lattice. Values of the dispersion function, which describes the off-momentum closed orbit, are also obtained.
- Particle Beam Calculations: The beam envelopes are calculated by using the betatron functions together with specified values of the emittances and momentum spread of the beam. For electron machines, one can compute natural emittances, damping, rf quantities, etc.
- Closed Orbit Calculations: One can compute the closed orbit, betatron functions and tunes through a circular accelerator for a particle with any momentum. Non-linear elements may be included in the accelerator description. Horizontal and vertical coupling can be studied.
- Particle Tracking: Particle trajectories can be printed either at all points of a beamline traversed once, or for each turn of a many-turn run at a single point of the ring.
- Non-linear Transformation Calculations: Point transformations, as well as those obtained by integrating differential equations, can be included. Some built-in routines are provided (*e.g.* beam envelopes with space charge), or users may provide their own.
- Element Misalignment Calculations: Closed orbits in the presence of transverse or rotational misalignments can be calculated. Also, random misalignments of selected elements can be generated.
- Orbit Correction Calculations: Closed orbit correction with kicker magnets in a lattice containing field errors or misalignments can be calculated.
- Fitting: Routines are present to achieve desired values of the betatron functions, dispersions, phase advances etc., by varying magnet parameters and drift lengths.

Table 1, which is reprinted from the forthcoming **SYNCH** Users Guide, summarizes the commands by function. The guide describes each command, mathematical formulation, input and output, and gives examples.

Table 1. **SYNCH** Program Commands, by Topic

Program Control	ACT	DEACT	RUN	SIZE	STOP
SYNCH Subroutines	CALL SUB	END VPAR	INCR	MESH	REPL
Mathematical Operations	CALC PARA	(SIN RAND	SQRT SUM	1/X VAR	etc.) =
Beamlines	BML	LIST			
Element Definitions	DEQ MAP	DRF NPOL	KICK ROTZ	MAG SOL	MAGV SXTP
Operations on Transfer Matrices	EQU REF	INV ROT	INV2 ROTZ	MMM **	MXV
General Matrix/Vector Definitions	MAT	MAT3	VEC		
Betatron Function Calculations	BETA TRKE	CYA TRKM	CYC	IBET	TRKB
Particle Beam Calculations	BVAL	CYAE	CYEM		
Fitting Routines	FITB SOLV	FITQ	FITR	FITV	SMIN
Closed Orbit Determination and Particle Tracking	FXPT	PVEC	TRK		
Element Misalignments	BMIS SHF7	EMIS	MAGS	MOVE	SHF
Orbit Correction	ORBC				
Plotting	BEP	BEST	TRKB		
Files	IOUT	KEEP	OPEN	UPDAT	SELCT
Output Statements	C PBML PTAB	ECHO PCYC REM	NECHO PRNT WBE	P PRTV WMA	PAGE PRTV7 .

NEW FEATURES IN **SYNCH**

New features incorporated in this 1993 version of **SYNCH** include calculations of transverse coupling parameters using the formalism of Edwards and Teng;[5] generalizing the calculation of the electron integrals, rf output, and electron emittance factors to include the effects of vertical bending; and optionally creating a new input file with updated parameters calculated by the fitting routines.

The new version of **SYNCH** is substantially coded in FORTRAN 77 so that the program is easily transportable to many operating systems and computer architectures. Also, portions of of the program have been re-coded for enhanced performance. Plots of the β (amplitude) and η (dispersion) functions through a beamline (with a schematic diagram of the magnet layout) are programmed with a GKS interface for increased portability (see Figures 1 and 2.) It is very probable that the UNIX and possibly the VAX/VMS versions of the code will be available as a complete package with the GKS platform included; testing is currently being done on a public domain version of GKS.

Final testing of the new draft versions of **SYNCH** is being done on a VAX/VMS and on Sun SPARCstations at the Superconducting Super Collider Laboratory.

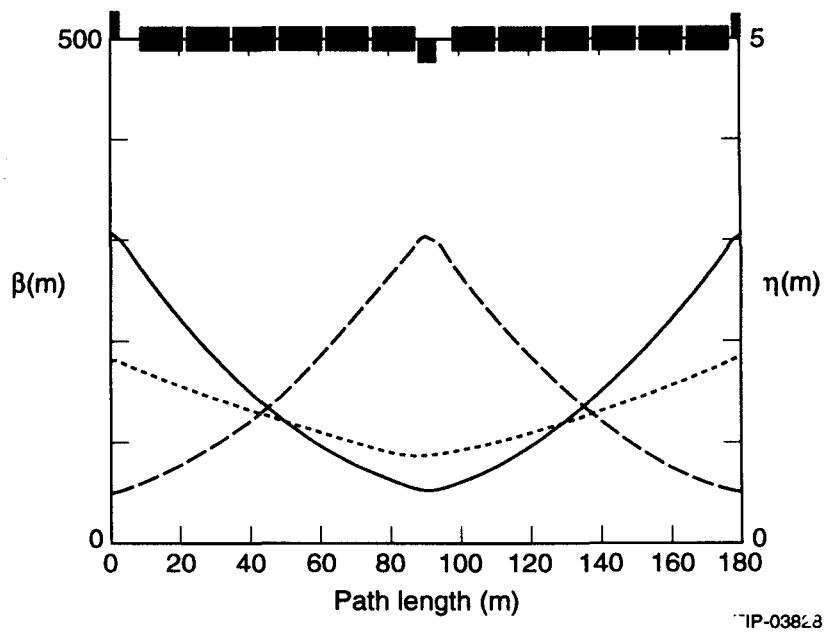

Figure 1. In this sample betatron-function plot, β_x is a solid line, β_y is a chain dash line, η_x is a dash line, and η_y is a chain dot line. Dipole magnets straddle the top horizontal line, focussing quadrupoles are above the line and the de-focussing quadrupole is below the line.

INTERACTION REGION DESIGN AT THE SSC

Most of the design effort on the SSC Interaction Regions has been done using **SYNCH**. The present status of the design will be reported at the 1993 IEEE Particle Accelerator Conference in May.[6] The most significant change since the 1990 Conceptual Design[7] is the procedure for the beta squeeze. Six families of independently powered quadrupole magnets change the optics from injection to collision while the strengths of the final-focus triplet quadrupoles are held constant. The phase advance from the Interaction Point (IP) to the arc quadrupoles was optimized to provide more effective positions of the local quadrupole and sextupole correctors for the IR. Two secondary focii where the IP is imaged have been incorporated symmetrically on both sides of the IR for beam diagnostics.

Other modifications include a significant reduction in the peak beta-function values at injection, optimized configuration of the M=-1 section, minimized number of different quadrupole lengths, standard field for the vertical bends and reduced total length of the magnets. The present design allows for a range of values between 40 to 180 meters for the space allocated to a detector at each IP, and for a range of β^* values from 7 to 0.25 meters for 40 meters detector space.

For each value of β^*, the gradients of the six variable strength quadrupoles were calculated to match the lattice functions into the arcs. The phase advance in each plane from the IP to the arc was also held constant. There were six conditions on the variables $\beta_x, \alpha_x, \eta_x, \beta_y, \alpha_y$, and η_y which were satisfied by using the fitting routine, **SOLV** on the six quadrupole gradients as parameters. Figure 2 is a plot of half an IR showing the amplitude and dispersion functions.

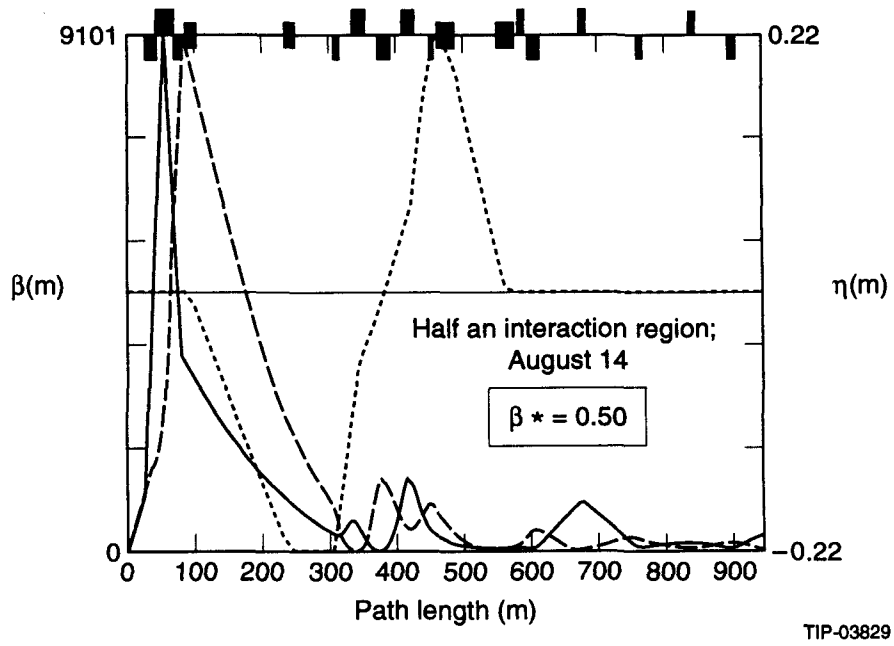

Figure 2. Betatron plot of one half of the IR with the schematic diagram of magnets at the top.

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