SSCL-N-725

WORKSHOP ON NONLINEAR PROBLEMS IN FUTURE PARTICLE ACCELERATORS*

Y. Yan

Physics Research Division
Superconducting Super Collider Laboratory†
2550 Beckleymeade Avenue
Dallas, Texas 75237

May 1990

*Presented at the Workshop on Nonlinear Problems in Future Particle Accelerators, April 18-25, 1990, Capri, Italy.

†Operated by the Universities Research Association, Inc., for the U.S. Department of Energy under Contract No. DE–AC02–89ER40486.

WORKSHOP ON NONLINEAR PROBLEMS IN FUTURE PARTICLE ACCELERATORS -- Held in Capri, Italy; April 18 - April 25, 1990 -- A BRIEF REPORT

Yiton Yan

Accelerator Division
Superconducting Super Collider Laboratory

May 1990

Nonlinear problems in accelerator physics were addressed in this workshop by many of the participants who were primarily European and American physicists. Topics discussed in the workshop ranged from specific features of the accelerators currently under design to the recent progress in mathematical physics.

The workshop started with an overview for each of the accelerators currently under design in the U.S. and in Europe (The HERA, the SSC, the LHC, and the RHIC). Preliminary studies for each accelerator were then presented in conjunction with the presentation of general mathematical descriptions of accelerator nonlinear dynamics. There were 41 presentations in total (refer to the Appendix). Presentations for the SSC were given by Richard Talman, Dave Ritson, and myself.

There were essentially no break-through presentations. But there were many important talks and discussions. A few of those which I found particularly impressive from the perspective of my interests were:

The normal form — an equivalence of Courant-Snyder invariance for higher order single-particle dynamics — were presented by European physicists Turchetti et al. with a mathematical approach different from the Lie algebraic approach. The results were the same (as they should be) as the work by Forest, Berz and Irwin two years ago. It is surprising that we were not (at least myself was not) aware of their work prior to this workshop (they may have performed this work quite a few years ago).

Alex Dragt presented his method for kick map factorization. Although some what similar to Irwin's method, his method leads to fewer kicks being necessary to represent a truncated Taylor series map of equivalent order and degrees of freedom.

Warnock presented his work (with Ruth) on long-term bound on nonlinear Hamiltonian motion. From an accelerator viewpoint, "long-term bound" is related to the dynamic aperture"

Irwin discussed kick factorization map. To make kick map tracking even faster, the possibility of cubic spline fitting of the kick map was discussed.

The SSC presentations also aroused considerable interest at the workshop. Colleagues in the workshop asked a lot of questions in Talman's talk on the SSC overview. After I presented the survival plots from "Ztrack" (a post-Teapot tracking program), they started to show strong

interest in figuring out a faster tracking method for the SSC aperture study. There are three candidates available: (a) Kick factorization map tracking presented by Irwin and improved by Dragt; (b) The "SSCTRK" — a lump scheme for SSC long-term tracking presented by Ritson; and (c) Extrapolation from million turn or hundred thousand turn Ztrack survival plots presented by myself.

Most of the attention are given to the first candidate - kick factorization map tracking. Some opposed it. Some supported it. Fundamentally, kick map should be all right if a very high order map is used. However, extracting a one-turn map (using "Zmap" and its associated vectorized differential agebra library "ZLIB") for the SSC with Synchrotron oscillation included would take about 20 hours CPU time in Cray for a 12th order map. Furthermore, the CPU time required for a 12th order kick factorization map tracking to a certain turn may have been in the same order of magnitude as that required for element by element tracking to the same turn using Ztrack. Therefore, to be practical, a low order kick map (less than 12th order) should be considered. Whether such a low order map works well remains to be justified.

Clearly, at present, we still want to further justify that the 5 cm magnet aperture is adequate. While some nonlinear techniques are still under development, the element-by- element long-term tracking appears to be the most reliable method to resolve this issue at this moment. It is possible now that we can perform life-time (seven million turn) tracking for the injection lattice of the SSC using the program Ztrack for very selective cases provided that the most powerful supercomputers are available to us. The code SSCTRK is currently able to perform life-time tracking for the SSC injection lattice and a few cases has been run. SSCTRK would be a sound tool for the SSC aperture study, if we could justify that the results (preferably the survival plots) are the same (statistical comparison with many random seeds), whether we use more super elements (lump less magnet elements together) than used in the normal SSCTRK or not.

There is no doubt that we should keep performing long-term element by element tracking at present. However, we should not give up our existing studies in mapping techniques. A vectorized and dynamic-memory differential algebra library, ZLIB, has been developed that should allow us perform Lie algebra easily. A "Zmap" is available that can extract a one turn Taylor map from Ztrack. Programs are available for performing Irwin factorization map track. In addition, there may exist new territories to be found in these numerical techniques that may eventually lead to a practical and reliable method for the SSC aperture study.

APPENDIX

1.	F. Willecke	HERA overview
2.	R. Talman	SSC overview
3.	J. Gareyte	LHC overview
4.	A.G. Ruggiero	Magnet error analysis in RHIC
5.	G. Turchetti	Normal form and stability in beam dynamics
6.	G. Szrvizi	PADE' approximation of normal form for area preserving maps
7.	J. Irwin	Kick factorization of a Taylor map
8.	A. Battani	Integrals of motion : perturbative and variational approach
9.	A. Giorgilli	Effective stability for realistic physical models
10.	J. Warnock	Long-term bounds on nonlinear Halmitonian motion
11.	A. Dragt	Methods for symplectic tracking
12.	F. Vivaldi	Discrete dynamics for strongly chaotic systems
13.	J. Gareyte	Magnetic errors
14.	E. Forest	A Hamiltonian-free description of complex periodic systems random multipolar errors
16.	K.O. Thielheim	Particle acceleration in extremely strong electromagnetic wave fields
17.	F. Schmidt	Sixtrack: a single particle trackingcode
18.	F.C. Iselin	Tracking with MAD in the presence of nonlinearities
19.	M. Berz	Description and analysis of circular accelerators with high order maps
20.	Y. Yan	Typical long-term tracking results for SSC aperture study
21.	D. Ritson	"SSCTRK" a simulation code for the SSC
22.	A. Giorgilli	Simple analytical approach for "Liapunov-exponent"
23.	R. Talman	Long term prediction and the SSC
24.	T. Bountis	Applications of 4-D mappings to the beam-beam interaction
25.	F. Willeke	Field errors on the SC magnets and dynamic aperture in HERA
26.	L. Vazquez	Some remarks about conservative and symplectic schemes Lunch pause
27.	E. Todesco	Correction scheme for LHC using normal forms
28.	G. Contopoulos	Transition to instability and chaos in 3-D Hamiltonians
29.	R. Talman	Experiments at Fermilab
30.	F. Schmidt	Experiments on diffusion at CERN-SPS

PANEL ON DIFFUSION (Experimental)

R. Talman, J. Gareyte, F. Schmidt, A.G. Ruggerio, F. Willeke

31.	J. Tennyson	Self-consistent beam dynamics at the beam-beam limit (symmetric and asymmetric ring colliders)
32.	V. Visnjic	Dynamic aperture of low beta lattices at tevatron collider
33.	Y. Kifer	Equilibrium states and random perturbations of dynamical systems
34.	A. Gerasimov	Phase convection: universal mechanism of lifetime limitation
35.	G. Mahmoud	On periodic orbits of non-linear dynamical systems with many degrees of freedom
36.	R. Xie	The functional equation arising from normal form theory
37.	S. Marmi	Existence of invariant circles for complex area-preserving maps
38.	M. Malavasi	Chaos transition ad diffusion in symplectic maps: some numerical results
39.	S. Petracca	Bifurcation of the longitudinal equilibrium distribution in electron storage rings
40.	M. Pusterla	Chaotic activity at Salerno University
41.	G. Dattoli	A unified treatment of optical and charged beam transport and of quantum squeezed states

CONCLUSIVE PANEL

W. Scandale (Chairman), J. Gareyte, A. Giorgilli, Y. Kifer, D. Ritson

A.G. Ruggiero, G. Turchetti, F. Willeke