

Visualization of the 4D Transversal Phase Space of Charged Particle Beams

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Abstract

STEVE, i.e. the “Space-Time-Enclosing Volume Extraction” algorithm is used here to generate continuous hypersurfaces, which enclose the occupied 4-cells of the discretized four-dimensional (4D) transversal phase space of a charged particle beam. The hypersurfaces are visualized, and hence provide the possibility to explore their true 4D shape features.

Introduction

Originally, STEVE [1] has been developed to determine so-called freeze-out hypersurfaces (FOHS) that may or may not be contained in 4D relativistic heavy-ion physics simulation data (*cf.*, e.g., Ref. [2]). The resulting FOHS are tetrahedral meshes of isothermal volumes that are embedded in a 4D $xyzt$ -space (space-time) under consideration.

STEVE [1] can be viewed as expansion into 4D of the three-dimensional (3D) surface generator VESTA [3]. In 3D, VESTA processes voxels and/or adequate 3D simulation data, whereas in 4D, STEVE processes toxels (i.e.,

time-varying voxels) and/or adequate 4D simulation data.

In 3D, the computation speed of VESTA is very high on both CPUs [3] (note the independent confirmation in Ref. [4]) and GPUs [5]. Likewise in 4D, STEVE is very efficient because it minimizes possible data redundancy by avoiding multiple counting of the manifold supporting points within the 4-cells, i.e., tesseracts (*cf.*, Ref. [1]).

Results

The visualization of shape features of the 4D transversal phase space of charged particle beams may lead to an optimization of the operation conditions of the particular particle sources [6]. In Fig. 1, we show for a $50 \times 50 \times 50 \times 50$ -sized toxel data set [6, 7] STEVE’s resulting hypersurfaces, i.e., the union of 129, 563 tetrahedrons in the 4D $xy'x'y$ -space. Note that all generated particles are enclosed here by choosing an iso-value of 1 for enclosure (*cf.*, Ref. [1]).

One can also probe the shape dependence of the extracted iso-hypersurface while intersecting them with 3D-subspaces (*cf.*, Ref.s [1, 8]). Such scans provide information about the dimensionality of the object in particular.

References

- [1] B. R. Schlei, “STEVE - Space-Time-Enclosing Volume Extraction”, (2013) arXiv:1302.5683 [cs.CG].
- [2] Yun Cheng, L. P. Csernai, V. K. Magas, B. R. Schlei, and D. Strottman, “Matching Stages of Heavy-Ion Collision Models,” *Phys. Rev. C* 81, 064910 (2010), doi: 10.1103/PhysRevC.81.064910.
- [3] B. R. Schlei, “Volume-Enclosing Surface Extraction”, *Computers & Graphics* 36 (2012) p. 111, doi: 10.1016/j.cag.2011.12.008.
- [4] T. Klemm, “Fortgeschrittenen-Praktikum: Der VESTA-Algorithmus”, *cf.*, <http://pille.iwr.uni-heidelberg.de/~vesta01>.
- [5] B. R. Schlei, “GPU Programming - Speeding Up the 3D Surface Generator VESTA”, GSI Scientific Report 2014 (2015) p. 460, doi: 10.15120/GR-2015-1-FG-GENERAL-42.
- [6] P. Spädtke, “The Role of Space Charge Compensation for Ion Beam Extraction and Ion Beam Transport,” *Rev. Sci. Instrum.* 85 (2014) 02A744, doi: 10.1063/1.4862661.
- [7] Courtesy of P. Spädtke, GSI, Darmstadt, Germany.
- [8] S. Biri, R. Rác, P. Spädtke, K. Tinschert, R. Lang, J. Mäder, F. Maimone, and B. R. Schlei, “Combination of two ECRIS calculations: Plasma electrons and extracted ions,” in *Proceedings of the ECRIS14, Nizhny Novgorod, Russia, 24-28 August, 2014* (Institute of Applied Physics of the Russian Academy of Sciences, Russia, 2015), p. 38.

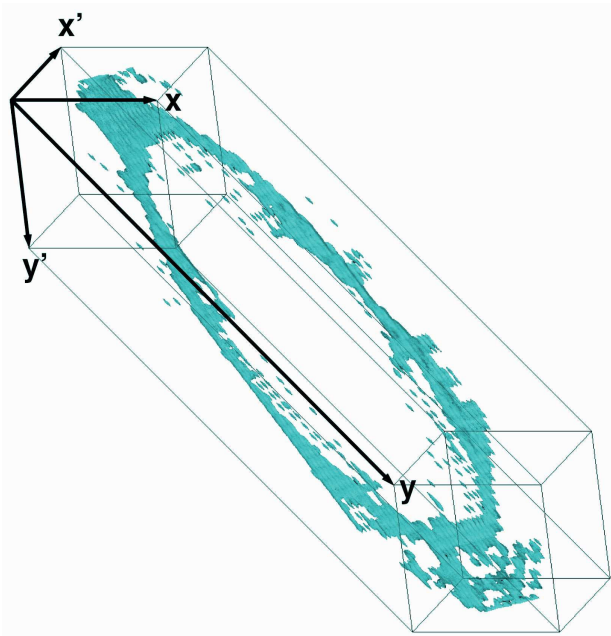


Figure 1: Projection of a tesseract containing the 4D simulation data [6, 7], together with all 4D hypersurfaces (i.e., volumes) generated by STEVE (taken from [1], see text).

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