Efficient and Precise Simulation of Particle Accelerators using Adaptive Meshes

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Accelerator Modeling and Advanced Simulation

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Theoretical Computer Science
Parallel Computing

Education and Academic Record

- **Paul Scherrer Institute**, Villigen, Switzerland. March 2013 - Feb 2015
  PSI-Fellow in the Department of Large Research Facilities. *AMAS, Dr. Adelmann*
- **ETH Zurich**, Switzerland. March 2013 -
  Lecturer in the Department of Computer Science. *Parallel Computing, Prof. Dr. Arbenz*
- **Stony Brook University**, New York, USA. May 2012 - Feb 2013
  PostDoc in the Department of Applied Mathematics and Statistics
  "Verification and Validation study of Large eddy simulations of turbulent mixing and combustion with a finite rate chemistry", in collaboration with Stanford University's Predictive Science Academic Alliance Program Center
- **Stony Brook University**, New York, USA. Feb 2006 - May 2012
  Ph. D. in Applied Mathematics & Statistics
  "Rayleigh Taylor Turbulent Mixing Simulations", Advisor: James Glimm
  The Woo Jong Kim Dissertation Award
  2010 Teaching Excellence Award
- **Istanbul Technical University**, Istanbul, Turkey. 2002 - 2004
  M. S. in Computational Science and Engineering, *Ranked 1st*
- **Yildiz Technical University**, Istanbul, Turkey. 1997 - 2001
  B. S. in Mathematics, *Ranked 2nd*

Research

The goal is to extend the high-performance algorithmic and software framework Object Oriented Parallel Accelerator Library (OPAL) used for general particle accelerator simulations with multi-scale capabilities.

- Static Adaptive Mesh Refinement (AMR) framework integration into iterative solver with a multigrid preconditioner to solve the Poisson problem
- Dynamic AMR framework integration into OPAL
- Application to PSI Ring start-to-end simulation with full halo characterization and/or self consistent model of the effect of dark currents in parts of the SwissFEL accelerator

Research

1. Get familiar with beam dynamics simulations and OPAL
2. Detailed study of AMR literature
3. Decide on **BoxLib**, a software framework for massively parallel block-structured adaptive mesh refinement

FASTMATH: Applied mathematics algorithms, tools, and software for HPC applications

- BoxLib: Tool for problem discretization, LBL
- Trilinos: Tool for Solution of Algebraic Systems, Sandia National Laboratory

✓ Interface constructed between BoxLib and Trilinos
BoxLib/Tutorials/AMR_Trilinos_C/

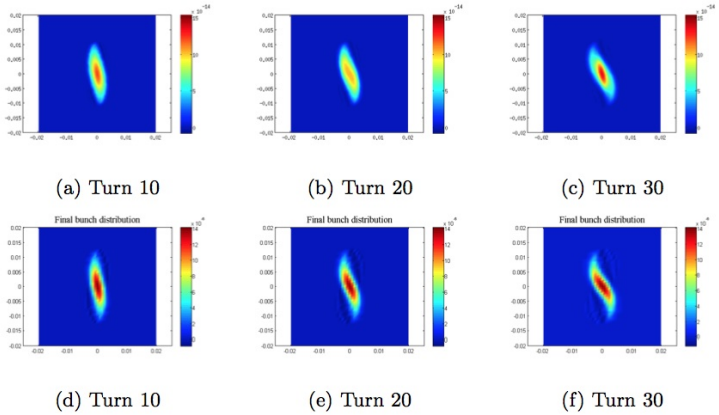
- Lawrence Berkeley National Laboratory (LBL), Center for Computational Sciences and Engineering, Berkeley, California, USA. December 1 - 23, 2013.

Contribution to the PhD, MSc and BSc Theses:

- "A Precise Beam Dynamics Model for the Beam Transport within the Gantry 3 Project", Foster A., PhD. candidate started in November 2013.

Uncertainty quantification of measurement and design variables

✓ "A Relativistic Fluid Model for Particle Beams in Cyclotrons", Stritt C., MSc. Comparison with "Analytic fluid theory of beam spiraling in high-intensity cyclotrons",A. J. Cerfon et.al., Phys. Rev. ST Accel. Beams, 16:024202, 2013.



(a) Turn 10 (b) Turn 20 (c) Turn 30

(d) Turn 10 (e) Turn 20 (f) Turn 30

✓ "Parallelization of Differential Algebra Framework", Frey M., BSc.

Scientific Activities I

- Minisymposiums Organizer at Society for Industrial and Applied Mathematics (SIAM) Conference on Uncertainty Quantification (UQ), Savannah, Georgia, USA. March 31-April 4, 2014.

UQ in Fluid Dynamics and Particle Accelerator Physics: I - II

Uncertainty quantification for simulations is a critical issue, as the models often constitute a primary source of uncertainty. We see how the specific requirements of diverse applications set the framework for justifying and assessing UQ methods.

- James Glimm, Stony Brook University, USA
- Johan Larsson, University of Maryland, USA
- Themistoklis Sapsis, Massachusetts Institute of Technology, USA
- Alan Calder, Stony Brook University, USA

- Tulin Kaman, ETH Zurich and Paul Scherrer Institute, Switzerland
- Roman Samulyak, Brookhaven National Laboratory, USA
- Jean Giorla, Commissariat a l'Energie Atomique, France
- Andreas Adelmann, Paul Scherrer Institute, Switzerland

Scientific Activities II

- Lecturer at ETH-Zurich, Department of Computer Science, "Introduction to Finite Elements and Sparse Linear System Solving", September 16 - December 20, 2013.
- Swiss National Supercomputing Center Autumn School on "GPU-enabled numerical libraries", September 14 - 15, 2013.
- Swiss National Supercomputing Center User Meeting, Lucern, Switzerland, September 6, 2013.
- Co-organizer of 42nd SPEEDUP Workshop on High Performance Computing, PSI, Villigen, Switzerland, August 29 - 30, 2013.
- 2013 European Trilinos User Group meeting, Technische Universität München, Munich, Germany, June 3 - 5, 2013.

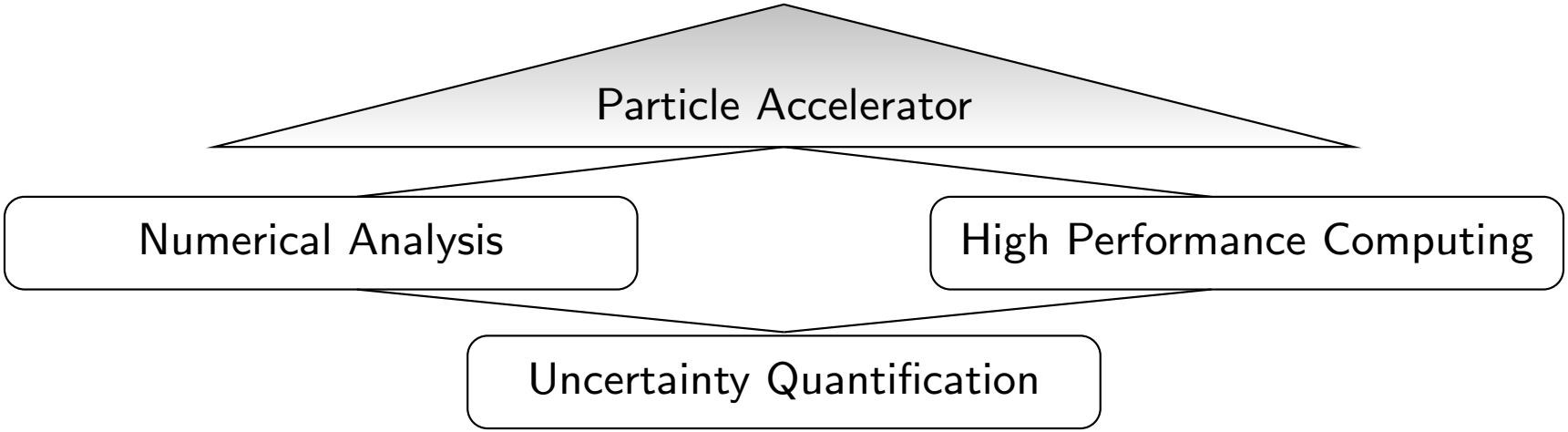
Papers in Preparation

- T. Kaman, A. Adelmann, P. Arbenz, A. Almgren, " New Adaptive Mesh Refinement Poisson Solver on Irregular Domains in Beam Dynamics Simulations", *Journal of Computational Physics*, Ready to submit in December.
- T. Kaman, A. Adelmann, P. Arbenz, A. Almgren, " Influence of Adaptive Mesh Refinement in Particle Accelerator Simulations", *Physics of Plasmas*, In Preparation.
- T. Kaman, A. Adelmann, P. Arbenz, "Uncertainty Quantification for Beam Dynamics Simulations", *SIAM/ASA Journal on Uncertainty Quantification (JUQ)*, In Preparation.
- A. Adelmann, T. Kaman, C. Stritt, "A Relativistic Fluid Model for Particle Beams in Cyclotrons", *Phys. Rev. ST Accel. Beams*, In Preparation.

1. J. Melvin, R. Kaufman, H. Lim, **T.Kaman**, P. Rao and J. Glimm 2013 "Macro and micro issues in turbulent mixing", Science China Technological Sciences, 1674-7321, pp.1-6 (2013). doi: 10.1007/s11431-013-5340-0
2. J. Glimm, D. H. Sharp, **T.Kaman**, H. Lim 2013 "New Directions for Rayleigh - Taylor Mixing", Philosophical Transactions of the Royal Society A, 371, pp.183 (2013). doi: 10.1098/rsta.2012.0183
3. **T.Kaman**, J. Melvin, P. Rao, R. Kaufman, H. Lim, Y. Yu, J. Glimm and D. H. Sharp 2013, "Recent Progress in Turbulent Mixing", Physica Scripta, 014051 (2013). doi: 10.1088/0031-8949/2013/ T155/ 014051
4. R. Kaufman, **T.Kaman**, Y. Yu and J. Glimm 2012, "Stochastic Convergence and the Software Tool W*", Proceeding Book of International Conference to honour Professor E.F. Toro, CRC, Taylor and Francis Group, pp.37-41 (2012).
5. **T.Kaman**, R. Kaufman, J. Glimm and D. H. Sharp 2012, "Uncertainty Quantification for Turbulent Mixing Flows: Rayleigh-Taylor Instability", IFIP Advances in Information and Communication Technology, Springer 377, 212–225 (2012).
6. H. Lim, **T.Kaman**, Y. Yu, V. Mahadeo, Y. Xu, H. Zhang, J. Glimm, S. Dutta, D. H. Sharp and B. Plohr 2012, "A Mathematical Theory for LES Convergence", Acta Mathematica Scientia 32, 1, pp.237-258 (2012).
7. **T.Kaman**, H. Lim, Y. Yu, D. Wang, Y. Hu, J.-D. Kim, Y. Li, L. Wu, J. Glimm, X. Jiao, X.-L. Li and R. Samulyak 2011, "A Numerical Method for the Simulation of Turbulent Mixing and its Basis in Mathematical Theory", Lecture Notes on Numerical Methods for Hyperbolic Equations: Theory and Applications: Short Course Book, CRC/Balkema, pp.105-129, London (2011).
8. **T.Kaman**, J. Glimm and D. H. Sharp 2010 "Uncertainty Quantification for Turbulent Mixing Simulations", 5th International Conference of Numerical Modeling of Space Plasma Flows (ASTRONUM 2010) 444, pp21 (2010)
9. **T.Kaman**, J. Glimm and D. H. Sharp 2010, "Initial Conditions for Turbulent Mixing Simulations", Condensed Matter Physics 13, 4, 43401: 1-7 (2010).

Future Career Plan:

As an Applied Mathematician: Continue to develop and apply advanced computational techniques



The diagnosis of errors in a multi-parameter, multi-physics setting is daunting, so I address this issue in turbulent mixing simulations. Future: apply to **particle accelerator simulations** and improve the performance of accelerators, including therapy machines.

- be a head of a research group
- raise funds and build networking
- publish in peer-reviewed journals

PSI-Fellow Programme

☺ Great support for attending seminars and conferences ⇒ building network ⇒ career management

☺ Offers opportunities for education and training in presentation-techniques and improvement of skills.

- "PSI-Fellow programme welcome meeting" in March 2013.
- "Career-starting" workshop by Dr. Monika Clausen in May 2013 was a success.

Suggestions:

- "Successful scientific writing: from proposal to publication" by Dr. Sarah Shephard (Spring & Autumn 2014) - could be in the first year.
- PSI-Fellow meetings in every 6 months to exchange experience.