Accelerator Simulation

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Seattle Snowmass Summer Meeting 2022
July 18th, 2022

Who We Are

- **Beam and Accelerator Modeling Interest Group (BAMIG)**
  - in CompF2: Theoretical Calculations and Simulation
  - Homepage: snowmass-compf2-accbeammodel.github.io
  - coordinator: Jean-Luc Vay (LBNL) - also CompF-AF liaison

- **Accelerator Simulation via Computer Modeling**
  - **essential** to beam & accelerator physics ***research***, as well as to the ***design, commissioning and operation*** of particle accelerators
  - contrary to machines & accelerator complexes, development of beam & accelerator physics ***codes often largely uncoordinated***
  - ***large, complex***: expanding range of ***intertwined physics*** topics
  - ***rapidly changing & disruptive*** computing hardware and software environments: from CPUs, GPUs over FPGAs to Quantum + AI/ML

What We Did

- Multi-year effort with regular bi-weekly meetings
  - **>80 people** in our mailing list, at least 1/3rd regularly active
  - **26 LOIs** (2020) snowmass-compf2-accbeammodel.github.io/loi/submitted.html

  - Journal of Instrumentation (JINST), ICFA Beam Dynamics Newletters #82: Advanced Accelerator Modeling (2021):
    - **Simulations of Future Particle Accelerators: Issues and Mitigations** by David Sagan, et al. DOI:10.1088/1748-0221/16/10/T10002
    - **Modeling of Advanced Accelerator Concepts** by Jean-Luc Vay, et al. DOI:10.1088/1748-0221/16/10/T10003

- Decided to amalgamate all inputs and topics into **one topical whitepaper** for Snowmass

Whitepaper to SM21, CompF

- **Collectively developed:** arXiv:2203.08335 (2022)
  Accelerator Modeling Community Whitepaper
  - further contributions to >4 whitepapers in AF and TF
    snowmass-compf2-accbeammodel.github.io/papers/submitted.html

Snowmass21 Accelerator Modeling Community White Paper

by the Beam and Accelerator Modeling Interest Group (BAMIG)*

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May 17, 2022

Key Topics Reported On

1. **Modeling needs** RF-based acceleration; Plasma-based wakefield acceleration; Structure-based wakefield acceleration; PetaVolts per meter plasmonics and Plasmonic acceleration; Materials modeling for accelerator design; Structured plasmas; Superconducting magnets
2. **To the next frontier: ultraprecise, ultrafast virtual twins of particle accelerators** Interdisciplinary simulations; End-to-end Virtual Accelerators (EVA); Virtual twins of particle accelerators
3. **Cutting-edge and emerging computing opportunities** Advanced algorithms; Artificial intelligence; machine learning, and differentiable simulations; Quantum computing; Storage ring quantum computers
4. **Computational needs** Hardware: CPU/GPU time, memory, archive; Software performance, portability and scalability; Scalable I/O and in-situ analysis
5. **Sustainability, reliability, user support, training** Code robustness, validation & verification, benchmarking, reproducibility; Usability, user support and maintenance; Training and education
6. **Toward community ecosystems & data repositories** Loose integration: Integrated workflows; Tighter integration: Integrated frameworks; Data repositories; Centers & consortia, collaborations with industry

High-Level Recommendations

1. Develop a **comprehensive portfolio** of particle accelerator and beam physics **modeling tools** in support of achieving Accelerator & Beam Physics Thrust Grand Challenges on intensity, quality, control, and prediction.
2. Develop **software infrastructure** to enable **end-to-end virtual accelerator modeling** and corresponding **virtual twins** of particle accelerators.
3. Develop **advanced algorithms and methods including AI/ML** modalities and **quantum computing** technologies.
4. Develop **efficient and scalable software frameworks** and associated tools to effectively leverage next generation **high-performance and high-throughput computing** hardware.
5. Develop **sustainable and reliable code maintenance** practices, community **benchmarking** capabilities, and **training** opportunities to foster the **cooperative** application of accelerator software.
6. Foster an **open community** that spans academia, national labs and industry to ***(a)*** develop **software ecosystems**, libraries, frameworks and standards, ***(b)*** curate **data repositories**, and establish dedicated **centers and distributed consortia with open governance models**.

Detailed Recommendations

Thank you for your attention!

- Please refer to our whitepaper for ***fine-grained detail recommendations on sub-topics***:
  arXiv:2203.08335 (2022)