HEP GARD Accelerator and Beam Physics: Community-driven Strategic Roadmap Workshop #2

WG2: Modeling and simulation tools (including energy deposition); fundamental theory and applied math.

Conveners: J.-L. Vay (LBNL), T. Zolkin (Fermilab), X. Huang (SLAC)

April 22-23, 2020

Organized by Fermilab – via Zoom

HEP GARD Accelerator and Beam Physics: Community-driven Strategic Roadmap Workshops

- Intro by Sergei Nagaitsev:
https://indico.fnal.gov/event/24124/contribution/0/material/slides/0.pptx

    o We are here to discuss the Accelerator and Physics research needs for the HEP and to define our long-term strategic road map.

- ABP Grand Challenges guiding long-term vision for roadmap:

    1. (beam intensity) Increase beam intensities by orders of magnitude.

    2. (beam quality) Increase beam phase-space density by orders of magnitude, towards quantum degeneracy limit.

    3. (beam control) Control the beam distribution down to the level of individual particles.

    4. (beam prediction) Develop predictive "virtual particle accelerators".

All accelerators in the world rely on theory & modeling
and increasingly on high-performance computing

CERN (HL-)LHC

LBNL BELLA

> *Next generation of accelerators needs*
> *next generation of theory & modeling tools!*
> GC#4: Develop predictive "virtual particle accelerators".

FNAL PIP(-II/III)

SLAC FACET (II) /LCLS-(II)

KEK-JPARC

LBNL ALS(-U)

Connections with workshop #1 (from summary report)

- **WG1: Single-particle dynamics, including nonlinearities, and spin dynamics.**
  - Strive for greater theoretical understanding; New analytical methods are needed.
  - Need for long-term particle tracking.
  - Realize virtual accelerators.

- **WG2: High-brightness beam generation, transport, manipulation and cooling.**
  - Although modeling is essential, no special comment in the summary. Expecting more in WK2-WG2.

- **WG3: Mitigation and control of collective phenomena.**
  - Impact of space charge on instabilities is not completely understood.
  - Simulations do not yet show required quantitative predictive power.
  - Confidence in predictions for future machines relies on validating the codes with data from existing facilities.
  - Need for better tools to model halos, wakefields, e-cloud effects.
  - Need for accurate simulations is common across all four grand challenges.

Connections with workshop #1 (from summary report)

- **WG4:**

  - **NCRF - Integrated modeling: merging beam dynamics and rf modeling for virtual prototyping.**
    - Examples of integrations (enabled through CAMPA collaboration):
      - a) RF field solver (ACE3P) with beam dynamics code (IMPACT), enabling virtual machine analysis;
      - b) ACE3P+IMPACT with plasma code (Warp) for studying plasma processing used for enhancing cavity performance;
      - c) ACE3P with Particle-Matter Interaction Code (FLUKA), enabling Modeling of Radiation for Machine Protection.

  - **SCRF - development of a predictive "virtual particle accelerator" that includes the features of an SRF acceleration system:**
    - Should allow optimization of design & operation regime, and to define technical and physical limitations.
    - Entails implementation of models for wakes in SRF acceleration systems (transition, transient, steady state, cavity components), high-order modes (HOMs) and dark currents.

  - **AAC**
    - Need for better code integration between beams and plasma PIC codes.
    - Need validation of CSR models (hosing seed) and effects at low emittance and high-peak currents.
    - Reduced models work well when appropriate (e.g., quasi-static in QuickPIC, HighPACE) but ultimately codes that scale to Exascale for modeling multiple stages and parameter scans (Warp-X Exascale development) will be required.

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WG2 outcomes

- Overview of current state of the art.

- Identify gaps.

- Establish

  ○ long range goals,

  ○ path forward,

  ○ (if possible) timetable.

Agenda – day 1 (April 22)

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Chair: Xiaobiao Huang

| 13:00 | **Introduction** | Jean-Luc VAY |
| | By Zoom | 13:00 - 13:15 |

| | **Analytical methods on nonlinear lattice design** | Stanislav BATURIN et al. |
| | By Zoom | 13:15 - 13:45 |

| | **Stochastic ODEs for Spin–Orbit Dynamics of Polarized e+ e- Beams** | Klaus HEINEMANN |
| 14:00 | By Zoom | 13:45 - 14:05 |

| | **Adjoint Methods Applied to Accelerator Lattices** | Thomas ANTONSEN |
| | By Zoom | 14:05 - 14:25 |

| | **Break** | |
| | By Zoom | 14:25 - 14:35 |

Chair: Jean-Luc Vay

| | **Modeling of intense beams** | Prof. John CARY et al. |
| | By Zoom | 14:35 - 15:05 |

| 15:00 | **Numerical tools in accelerator simulations** | Dr. Eric STERN et al. |
| | By Zoom | 15:05 - 15:35 |

| | **Discussion** | |
| | By Zoom | 15:35 - 16:00 |

| 16:00 | | |

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Agenda – day 2 (April 23)

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Chair: Tim Zolkin

Time		
13:00	**Numerical challenges in the modeling of highly nonlinear rings with intense space charge / Beam Equilibria and Halo Mitigation Mechanisms for Intense Beams**	*Chad MITCHELL et al.*
	By Zoom	13:00 - 13:30
	CSR modeling and 3D analysis	*Dr. Yunhai CAI et al.*
	By Zoom	13:30 - 14:00
14:00	**Designing structured plasmas for next generation hadron and lepton accelerators**	*Dr. Nathan COOK*
	By Zoom	14:00 - 14:20
	Simulation tools for beam-induced energy deposition effects	*Dr. Nikolai MOKHOV*
	By Zoom	14:20 - 14:40
	Break	
	By Zoom	14:40 - 14:50

Chair: Jean-Luc Vay

Time		
15:00	**Virtual accelerator, high-performance computing, standards / A collaborative approach to meeting beam physics grand challenges via open source cloud computing**	*Jean-Luc VAY et al.*
	Discussion	
16:00	By Zoom	15:20 - 16:20

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