# Summary of the "Workshop on Beam Acceleration in Crystals and Nanostructures" (Fermilab, June 24-25, 2019)*

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Here we present a short summary of the "Workshop on Beam Acceleration in Crystals and Nanostructures" which has taken place at Fermilab on June 24-25, 2019.

*Keywords*: Accelerators; crystals; carbon nanotubes; nanostructures.

## 1. General information about the Workshop

The concept of beam acceleration in solid-state plasma of crystals or nanostructures like CNTs (or alumna honeycomb holes) has the promise of ultra-high accelerating gradients O(1-10) TeV/m, continuous focusing and small emittances of, e.g., muon beams and, thus, may be of interest for future high energy physics colliders. The goal of the "Workshop on Beam Acceleration in Crystals and Nanostructures" which took place at Fermilab on June 24 and 25, 2019, was to assess the progress of the concept over the past two decades and to discuss key issues toward proof-of-principle demonstrations and next steps in theory, modeling and experiment. The Workshop was endorsed by the American Physical Society (APS) Division of Physics of Beams (DPB) and the APS Topical Group in Plasma Astrophysics (GPAP), the International Committee on Ultra-High Intensity Lasers (ICUIL) and the International Committee on Future Accelerators's Panel on Advanced and Novel Accelerators (ICFA ANA).

The Workshop had 40 participants from 6 countries, representing all relevant areas of research such as accelerators and beam physics, plasma physics, laser physics, and astrophysics. More than 20 presentations covered a broad range of topics relevant to acceleration in crystals and carbon nanotubes (CNTs), including:

1. overview of the past and present theoretical developments toward crystal acceleration, ultimate possibilities of the concept;
2. concepts and prospects of PeV colliders for HEP;

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3. effective crystal wake drivers: beams, lasers, other;
4. beam dynamics in crystal acceleration;
5. instabilities in crystal acceleration (filamentation, etc.);
6. acceleration in nanostructures (CNTs, etc);
7. muon sources for crystal acceleration;
8. application of crystal accelerators (X-ray sources, etc.);
9. astrophysical evidence of wakefield acceleration processes;
10. steps toward "proof-of-principle": 1 GeV gain over 1 mm, open theory questions, modeling and simulations;
11. possible experiments at FACET-II, FAST, AWAKE, AWA, RHIC, LHC, CEBAF, or elsewhere

There were many vivid discussions on these subjects. All the talks and summaries of the discussions are available at https://indico.fnal.gov/event/19478/ .

## 2. Major Outcomes

Several interesting proposals for further explorations or experimental tests were made by Sahel Hakimi, *et al*. (University of California, Irvine, on how to drive wakes in CNTs by ultimate or existing X-ray pulses from, e.g., the LCLS SASE FEL); by Aakash Sahai, *et al.* (University of Colorado, on production of detectable number of muons and their subsequent acceleration either at BELLA or FACET-II facilities); by Vladimir Shiltsev, *et al.* (Fermilab, on demonstration of effective micromodulation of electron beams at FAST and FACET-II and subsequent experiments with micromodulated beams sent through CNTs at FAST with kA peak current type beams and then at the FACET-II facility with upto 300 kA bunches, e.g., to demonstrate the CNT channeling or to study the electron beam filamentation phenomena in structured materials); by Gennady Stupakov (SLAC, on possibility to use 1-nm-SASE-modulated electron bunches at the end of LCLS-I undulators to excite crystals and demonstrate acceleration); by Johnathan Wheeler, *et al.,* (Ecole Polytechnique, to use the APOLLO laser facility to demonstrate Peta-Watt optical pulses/single cycle pulses via thin-film-compression technique); by Valery Lebedev (FNAL, to explore effectiveness of the wake excitation in crystals or CNTs by high-$Z$ high energy ions, e.g. by 450 GeV ion beams from the CERN SPS available at the AWAKE facility, and observation of possible acceleration of externally injected electrons).

Formation of the research teams has began and follow-up presentations are being planned for the FACET-II Annual Science Workshop (SLAC, October 29 – November 1, 2019).

These Proceedings of the Workshop are co-edited by Profs. Gerard Mourou (Ecole Polytech, 2018 Nobel Prize in Physics), Toshiki Tajima (UCI), Swapan Chattapdhyay (NIU) and Vladimir Shiltsev (Fermilab).


Fig. 1. Group photo of the Workshop.