Planning and Conducting Experiments at the FAST Linac and IOTA Ring

Giulio Stancari for the
IOTA/FAST Scientific Committee (ISC)

IOTA/FAST Collaboration Meeting
Fermilab, October 27-29, 2021

indico.fnal.gov/event/50565

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Motivation

The facility is dedicated to **research** and **education** in beam physics and accelerator technology

The IOTA/FAST Scientific Committee works with the experimenters to achieve these goals:

- Encourage a **vibrant scientific program**
- Establish transparent resource and schedule **priorities**
- Ensure adequate **planning** of experiments
- **Document** research done at the facility
- **Keep the process simple**, to serve a flexible facility with frequent apparatus modifications and experiments running in parallel

Resources on the IOTA/FAST Scientific Committee Web Page

IOTA »

IOTA/FAST Scientific Committee (ISC)

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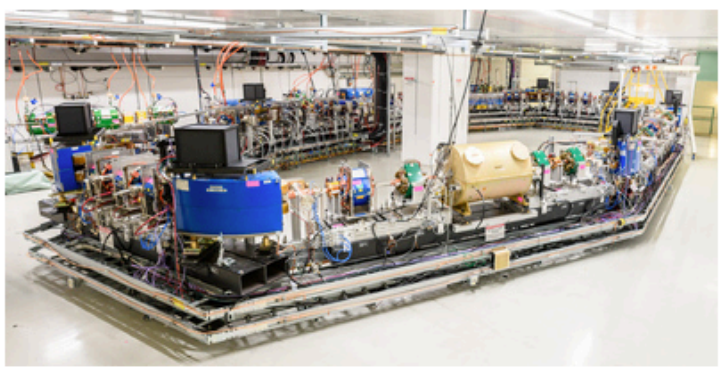
Proposing an experiment at IOTA/FAST

- Proposal submission guidelines: Beams-doc-7363
- Proposal template [PDF] [LaTeX]
- Note on data storage options for IOTA/FAST experiments: Beams-doc-8245

- Presentation given at the FAST/IOTA Collaboration Meeting (June 2020)
- Presentation given at the FAST/IOTA Collaboration Meeting (June 2019)



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(Some Fermilab pages are temporarily restricted to registered users. Key documents can also be found in this presentation's Indico links.)

cdcvs.fnal.gov/redmine/projects/ifsc/wiki/

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Experiments in Run 3 (Oct 2020 - Aug 2021)

7 experiments were carried out: 2 in the FAST Linac and 5 in IOTA.

Run 3 (8 Oct 2020 - 29 Aug 2021)

IOTA

ID	Acronym	Title	Spokesperson	LOI (optional)	Proposal	Presentation	Status	Beam Time	Reports
I-307	BOPTSE	Proof of principle studies on betatron oscillations phase tracking of a single electron	A. Romanov (FNAL)	no	PDF	Fri Aug 20, 2021	approved	3 x 8 h + 2 x 4 h	
I-306	OSC/SSOCs	Optical Stochastic Cooling Experiment: Systematic Studies of OSC Concepts	J. Jarvis (FNAL)	no	PDF	weekly reports	approved	7 weeks, 80% of IOTA uptime	
I-305	OSC/DEMO_1	Optical Stochastic Cooling Experiment: Demonstration Experiment	J. Jarvis (FNAL)	no	PDF	weekly reports	approved	4 weeks, 80% of IOTA uptime	
I-304	OSC/APP_COMM	Optical Stochastic Cooling Experiment: Apparatus Commissioning	J. Jarvis (FNAL)	no	PDF	weekly reports	approved	8 weeks, 80% of IOTA uptime	JINST Design Report
I-303	URSSE	Measurement of Spontaneous Undulator Radiation Statistics Generated by a Single Electron	S. Nagaitsev (FNAL/UChicago)	no	PDF	Fri Apr 2, 2021	approved	3 x 8 h	

FAST Linac

ID	Acronym	Title	Spokesperson	LOI (optional)	Proposal	Presentation	Status	Beam Time	Reports
I-302	LRW/SRW	Investigations of Long-range and Short-range Wakefield Effects on Beam Dynamics in TESLA-type Superconducting Cavities	A. Lumpkin (FNAL)	yes	PDF	Oct 2, 2020	approved	6 x 8 h	Diaz IPAC21 MOPAB289 Lumpkin IPAC21 TUPAB272 Lumpkin IPAC21 TUPAB273 Lumpkin IPAC21 TUPAB274 Sikora IPAC21 MOPAB323 Thurman-Keup IPAC21 MOPAB232
I-301	ElegantACL	Elegant- and ACL-Based Trajectory Tuning for the FAST Facility	J. Ruan (FNAL)	no	PDF	Sep 11, 2020	approved	3 x 8 h	

cdcvs.fnal.gov/redmine/projects/ifsc/wiki/

Background on Experiments and Proposals

Proposals can be submitted any time. The ISC meets regularly, with special meetings as needed (e.g., during a run, when new ideas may emerge)

An '**experiment**' is defined by the scope of the proposal and it is **completed within one experimental run**.

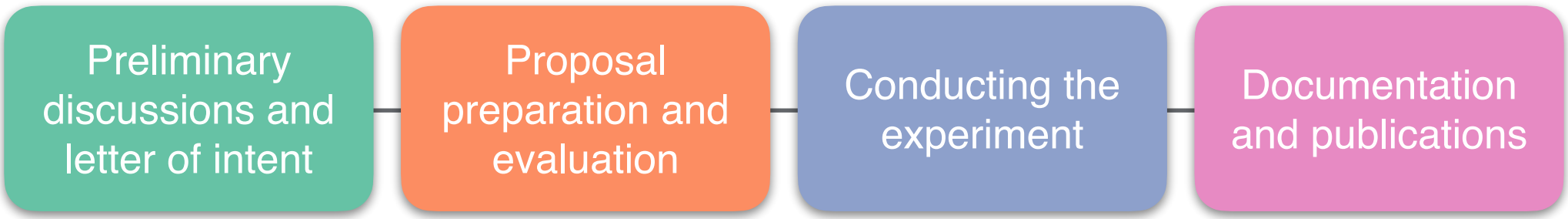
A '**research program**' can span **multiple runs** and include **more than one experiment or proposal** (e.g.: nonlinear integrable optics, optical stochastic cooling, undulator radiation from single electrons)

Experiments designate a **Spokesperson** or Principal Investigator (PI) and, optionally, a **Deputy Spokesperson**. If both are external, a **Fermilab Liaison** must be identified.

[Note: External collaborators register as Fermilab Users within the *FAST/IOTA Collaboration*, which acts as a general *umbrella organization for administrative purposes*]

Information and Comments on the Experiment Cycle

Main components of an experiment:



Preliminary Discussions and Letter of Intent

The project is discussed with interested parties and with Fermilab staff.

A **letter of intent** is sent by e-mail to one of the members of the ISC. The LOI is an **informal written document** (from a few paragraphs up to 4 pages).

The LOI helps define the scope of the experiment, makes the ISC aware of the request, and starts the proposal preparation process.

The LOI is optional, but recommended.

Proposal Preparation and Submission

The **formal proposal** is a **detailed written document** describing the scientific and technical aspects of the experiment.

The proposal includes:

- title
- personnel, with specific roles and responsibilities [e.g., see casrai.org/credit]
- purpose and methods
- required beam conditions
- apparatus and necessary infrastructure
- run plan and shift request
- internal and external resources
- supporting documents and other relevant information

A template with instructions is available on the ISC web site
cdcvs.fnal.gov/redmine/projects/ifsc/wiki

The **written proposal** is sent by e-mail to the ISC. An **oral presentation** is scheduled to discuss the proposal.

A well prepared and well written proposal is essential for the success of an experiment.

Updated proposal template

Experiment Title (ACRONYM)

Author One* and Author Two†

Institution A

Author Three‡ and Author Four

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I. GENERAL INFORMATION

This template and its LaTeX source code are meant to aid researchers in covering all relevant aspects of proposal preparation and experiment planning for the IOTA/FAST facility at Fermilab. Researchers may use the software of their choice when writing the document. The proposal is to be submitted in PDF format to the IOTA/FAST Scientific Committee. Please remove instructions in italics before submission.

- *Use a synthetic and descriptive title. Choose an experiment acronym with fewer than 16 characters.*
- *Indicate the name, institution, phone number and e-mail of the Spokesperson or Principal Investigator, Deputy Spokesperson or co-PI (optional) and Fermilab Liaison (necessary if spokesperson and deputy spokesperson are not Fermilab employees).*
- *List collaborator names and institutions.*
- *The role of each collaborator is to be listed in Section VI.*

II. PURPOSE AND METHODS

Describe the following aspects:

- *Background information*
- *Scientific or technical motivation and purpose*
- *Experimental methods*
- *Expected results and sources of uncertainty*

III. BEAM CONDITIONS

List the values and ranges of requested beam parameters, specifying any constraints on accuracy or stability: species, intensity, energy, number of bunches, transverse emittance, beam size, bunch length, momentum spread, time structure. Does the experiment require lattice, orbit or other modifications?

* Principal Investigator; email: author.one@institution.a; phone: (123) 456-7890
† Co-PI; author.two@institution.a
‡ Fermilab Liaison; author.three@fnal.gov

Each section contains questions and checklists to help collaborators cover all aspects of the experiment

Scientific and Technical Reviews

The **scientific review** is carried out by the ISC. Evaluation is based upon scientific merit, as defined, for instance, by current literature, support of independent experts or relevance to the Fermilab program.

The **technical review** is coordinated by the Head of the FAST Facility Department. It includes safety, feasibility, resource availability, schedule and impact on other projects.

The **outcome** of the reviews may be

- ***rejection*** — with written motivation
- ***deferral*** — if more preparatory work is needed
- ***approval*** — the experiment is included in the experimental program and operations schedule

Scheduling and Data Taking

For approved experiments:

- The **schedule** is determined by the **Run Coordinator**
- The shift schedule takes into account **priorities** and **compatibility** with other studies
- The schedule incorporates **flexibility**
  - to allow external collaborators to participate
  - to mitigate the challenges of simultaneously setting up experiments, collecting data, and running preliminary analyses
- Experimenters are expected to give **brief periodic updates** during the run (e.g.: 10-minute status reports at the weekly Friday meetings)

Documentation and Publications

It is expected that approved experiments

- **Maintain a web site** with documents, pictures, data, computer code, internal notes, papers, etc. Infrastructure at Fermilab is available through Fermi Redmine, if experimenters choose this option. Dedicated data storage is also available.

We have made progress, but we need to do a better job. Documentation and reproducibility of research is essential. Moreover, tools developed for one experiment may be useful for other studies.

- **Publish results** as soon as possible (at least one report within 6 months of run). There are various publication **options**, depending on the nature of the results:
  - peer-reviewed **journals**: *Phys. Rev. Accel. Beams*, *Nucl. Instrum. Methods*, *J. Instrum.*, …
  - conference **proceedings**: IPAC, LINAC, …
  - Fermilab **reports**:
    - » physics notes (FERMILAB-FN)
    - » technical memos (FERMILAB-TM)
  - Accelerator Division **notes**:
    - » Beams-doc: (beamdocs.fnal.gov)

Very good publication record from IOTA/FAST so far

A Dedicated Channel: JINST Special Issue

Special Issue of JINST dedicated to IOTA, thanks to Vladimir Shiltsev as member of the Editorial Board for the initiative

Wide scope: theory and modeling; experimental results; technical reports; instrumentation

Alexander Valishev and I serving as **Editors**

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Journal of Instrumentation

Accelerator Science and Technology Research at the Fermilab Integrable Optics Test Accelerator

Editors

Giulio Stancari and Alexander Valishev from Fermi National Accelerator Laboratory

The Integrable Optics Test Accelerator (IOTA) at Fermilab is a storage ring dedicated to beam physics research. Its purpose is threefold: to address the challenges posed by future high-intensity machines, such as instabilities and losses; to carry out basic research in beam physics; and to provide education and training for scientists and engineers.

IOTA is unique in its research mission, as well as in its flexibility and accuracy. It has a circumference of 40 m and a relatively large aperture (50 mm). It is easily reconfigurable to accommodate the installation of different experiments. Because of the quality of the instrumentation, the magnetic lattice can be precisely controlled. In addition, the lattice was designed to have significant flexibility to enable a wide variety of studies. IOTA can store electrons up to 150 MeV or protons at 2.5 MeV.

Because of synchrotron-radiation damping, electrons are suited to the study of linear and nonlinear single-particle effects. Proton dynamics, on the other hand, is dominated by space charge. Electrons were circulated for the first time in August 2018. Proton beams will become available in 2021 and will open up research on high-intensity beams.

The IOTA research program includes the experimental study of nonlinear integrable focusing systems based on special magnets or on electron lenses. Because of their nonlinearity, these systems generate a betatron tune spread that protects the beam from instabilities through Landau damping. Integrability ensures that the nonlinear system does not reduce the dynamic aperture of the machine, therefore preserving beam lifetime and emittance. Several other topics will be studied in IOTA, such as the experimental demonstration of optical stochastic cooling and the compensation of space-charge effects. In addition, IOTA has the capability of storing single electrons. Experiments on the spatial and temporal distribution of undulator radiation from single electrons are under way.

This Special Issue of the Journal of Instrumentation includes articles on the research conducted at IOTA, technical reports on the facility, descriptions of the instrumentation used for beam diagnostics, and discussions of the experimental results.

Giulio Stancari and Alexander Valishev
Fermi National Accelerator Laboratory

https://iopscience.iop.org/journal/1748-0221/page/extraproc90

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Papers

The design of Optical Stochastic Cooling for IOTA
V. Lebedev *et al* 2021 *JINST* **16** T05002
+ Open abstract View article PDF

Averaged invariants in storage rings with synchrotron motion
S. Webb *et al* 2020 *JINST* **15** P12032
+ Open abstract View article PDF

Single-particle dynamics in a nonlinear accelerator lattice: attaining a large tune spread with octupoles in IOTA
S.A. Antipov *et al* 2017 *JINST* **12** P04008
+ Open abstract View article PDF

OPEN ACCESS
IOTA (Integrable Optics Test Accelerator): facility and experimental beam physics program
S. Antipov *et al* 2017 *JINST* **12** T03002
+ Open abstract View article PDF

IOTA physics articles from the ICFA Beam Dynamics Newsletter #81

Design of a compact, cryogen-free superconducting solenoid for the electron lens of the Fermilab Integrable Optics Test Accelerator (IOTA)
R.C. Dhuley *et al* 2021 *JINST* **16** T03009
+ Open abstract View article PDF

Calculations of detuning with amplitude for the McMillan electron lens in the Fermilab Integrable Optics Test Accelerator (IOTA)
B. Cathey *et al* 2021 *JINST* **16** P03041
+ Open abstract View article PDF

Self-consistent PIC simulations of ultimate space charge compensation with electron lenses
E. Stern *et al* 2021 *JINST* **16** P03045
+ Open abstract View article PDF

Landau Damping with Electron Lenses in Space-Charge Dominated Beams
Y. Alexahin *et al* 2021 *JINST* **16** P03046
+ Open abstract View article PDF

McMillan electron lens in a system with space charge
S. Nagaitsev *et al* 2021 *JINST* **16** P03047
+ Open abstract View article PDF

Progress in space charge compensation using electron columns
C.S. Park *et al* 2021 *JINST* **16** P03048
+ Open abstract View article PDF

Beam physics research with the IOTA electron lens
G. Stancari *et al* 2021 *JINST* **16** P05002
+ Open abstract View article PDF

Several articles already included

Examples of upcoming candidate contributions:

- experimental results from Runs 1, 2 and 3
- diagnostic systems (beam-position monitoring, synchrotron radiation, …)
- nonlinear integrable optics models and simulations

https://iopscience.iop.org/journal/1748-0221/page/extraproc90

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Proposal submission guidelines

Beams-doc-7363-v1 — June 6, 2019

Proposing an experiment at IOTA/FAST

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Fermi National Accelerator Laboratory, P.O. Box 500, Batavia, Illinois 60510, USA

INTRODUCTION

The Integrable Optics Test Accelerator (IOTA) and its injector, the Fermilab Accelerator Science and Technology (FAST) superconducting electron linac, are facilities dedicated to research and education in beam physics and accelerator technology [1, 2]. Current areas of research include the dynamics and control of hadron beams with strong self fields for high-energy physics; the experimental demonstration of nonlinear integrable optics; stochastic beam cooling at optical frequencies; magnetized beams for electron cooling; quantum properties of radiation from single electrons; beam dynamics in superconducting cavities; advanced beam diagnostics; and others.

This document is meant to help Fermilab scientists and engineers and their external collaborators in the process of proposing and carrying out experiments at IOTA/FAST.

https://beamdocs.fnal.gov/cgi-bin/sso/ShowDocument?docid=7363

Outlook: Run 4 and Beyond

Proposals and **new concepts** will be presented during experiment reports and during next sessions. Looking forward to stimulating discussions.

Expecting beam time requests for Run 4 (2022) on:

- **IOTA**
  - Nonlinear integrable optics (nonlinear magnet and octupoles)
  - Instability thresholds and nonlinear optics
  - Single-electron phase-space tracking
  - Undulator radiation interferometry
- **FAST Linac**
  - Enhanced radiation amplification in tapered undulators (TESSA)
  - Noise in electron bunches

Plans to be discussed at this meeting and after. New proposals are welcome.

Reminders

It is time to **submit the Run 3 experimental reports**. The final deadline is February 28, 2022.

During the **Run 3 experimental talks** at this meeting, please address:

- shift summary
- main results so far
- data storage and backup plan
- experiment web site location
- publication plans

Conclusions

The IOTA/FAST facility is dedicated to **research** and **education** in **beam physics** and **accelerator technology**. An active and vibrant **research program** has started.

The **IOTA/FAST Scientific Committee** (ISC) **formulates priorities**, **reviews proposals**, and **oversees experiments**.

Experimental results will be presented at this meeting. We would also like to discuss **plans** for the near future and for the upcoming years.

Although progress was made, we need to **improve** on **proposal preparation** and **documentation of experiments** and **subsystems**.

Very good results so far in terms of **personnel development** and **publication record**. Always looking for motivated scientific and technical new staff and early-career researchers.

New ideas and **proposals are welcome** — they are the foundation of the scientific program.

Thank you

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