Research at FAST/IOTA: Strategy and Priorities

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2021 IOTA/FAST Collaboration Meeting

27 October 2021

IOTA/FAST Strategic Goals – Unchanged

- **Complete the FAST facility construction and commissioning**
  1. Assemble and commission the IOTA proton injector
  2. Commission IOTA with proton beams
  3. Complete the commissioning of FAST SRF linac
- **Plan and execute the experimental program at IOTA and in the injector machines**
  1. Conduct high-priority research in IOTA
  2. Develop IOTA experimental capabilities
  3. Allow concurrent experiments in IOTA and FAST as afforded by resources
- **Expand the IOTA/FAST Collaboration**
  1. Establish efficient facility operations
  2. Develop the collaborative proposal-driven framework
  3. Establish FAST as training center

Priorities

In developing the priorities and schedules we balance present research capabilities, potential impact and available resources

I. **IOTA research focused on beam intensity and brightness in proton rings mostly driven by the development of Fermilab's high-energy neutrino program**
   - Prerequisite is the completion of the proton injector and IOTA commissioning with protons
   - Research that can be done with present capabilities

II. **High-impact science aligned with GARD mission**

III. **Collaboration-driven research seeding potentially high-impact directions**

I. Research Focused on Beam Intensity in Rings

Key components of this research topic are

- **Suppression of coherent instabilities via Landau damping**
  - Can be studied with ***both*** **electrons and protons**
  - Possible technologies
    - Nonlinear Integrable Optics
    - Electron Lenses
- **Mitigation of space-charge effects**
  - **Requires proton beam in IOTA**
  - Possible technologies
    - Nonlinear Integrable Optics
    - Electron Lenses
    - Electron columns

II. High-Impact GARD Research

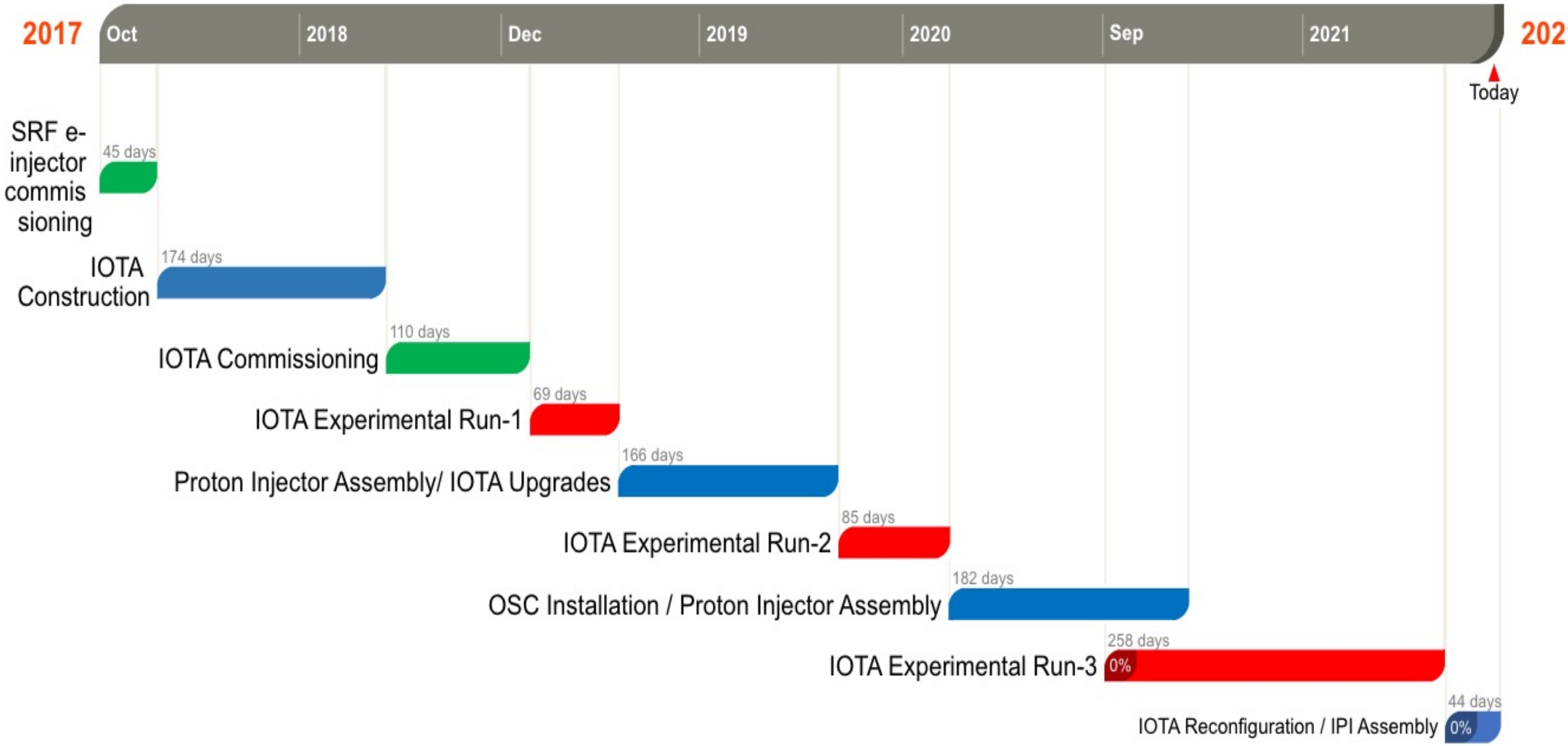
- **Nonlinear Integrable Optics**
  - Can be studied with electrons
  - Several options for implementation: octupole lenses, elliptic-potential magnet, electron lenses
- **Optical Stochastic Cooling**
  - Can do now with electrons
- **Development of novel beam instrumentation**
  - Large dynamic range halo monitoring
- **SRF acceleration: beam intensity and brightness**
  - Achievement of ILC beam acceleration and beam parameters

III. Collaboration-Driven Research & Development

- Radiation generation
- Electron-Ion Collider R&D
- Collaboration with other beam facilities and projects
  - FACET-II and other accelerator test facilities
  - LCLS-II
  - PIP-II
- Quantum science
- Education and training

Approach to Realization

- Balance priorities and resources
- Interleave facility development with beam runs
- Staged approach to research



Research Staging

Nonlinear Integrable Optics

- Phase I – research concentrates on the academic aspect of single-particle motion stability using electron beams
  - Run-1 2019, Run-2 2020
- Phase II – intense-beam studies with protons
  - 2021 and beyond

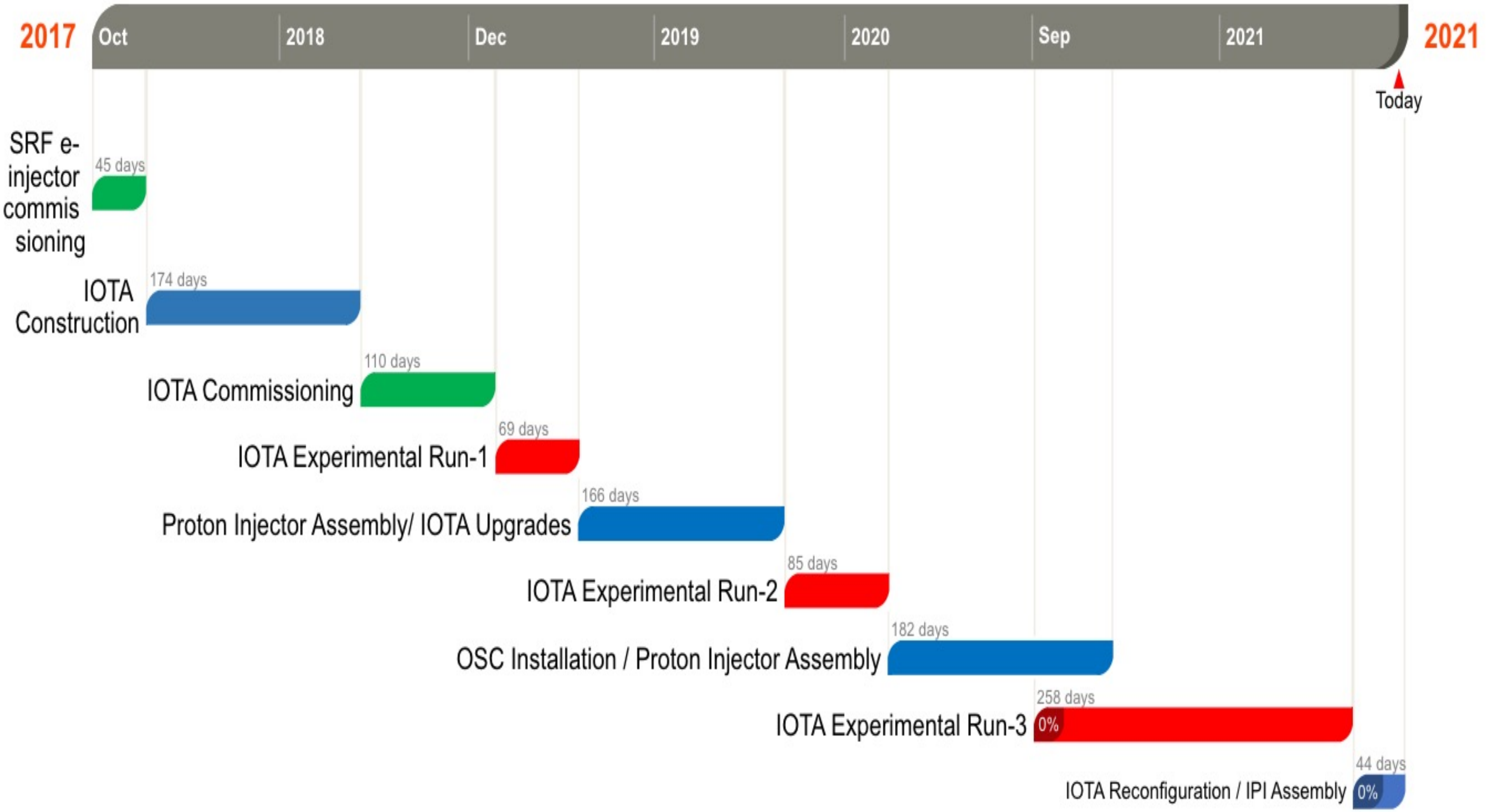
Optical Stochastic Cooling

- Without optical amplifier
  - Run-3 2020-21
- With optical amplifier

IOTA/FAST Team

- FAST Facility Dept – Accelerator development, maintenance and operations
  - Research support personnel
- Accelerator Research Dept – Planning and execution of research program
  - Scientific staff
  - Postdocs and students (2×PhD graduates this year!)
- Support Depts (on-demand) – Mechanical Support, Electrical Engineering, Controls, Instrumentation
  - Effort is shifted around to support FAST/IOTA and other laboratory activities – very efficient and eliminates ”Standing-Army” issues
- Collaborators

IOTA/FAST Recent Timeline



Research in IOTA/FAST Experimental Run 2

Broad program: in all 9 experiments took data over 60 shifts and produced relevant results. Engagement of outside collaborators (CERN, SLAC, Jlab, Uchicago, NIU) and 6 graduate students.

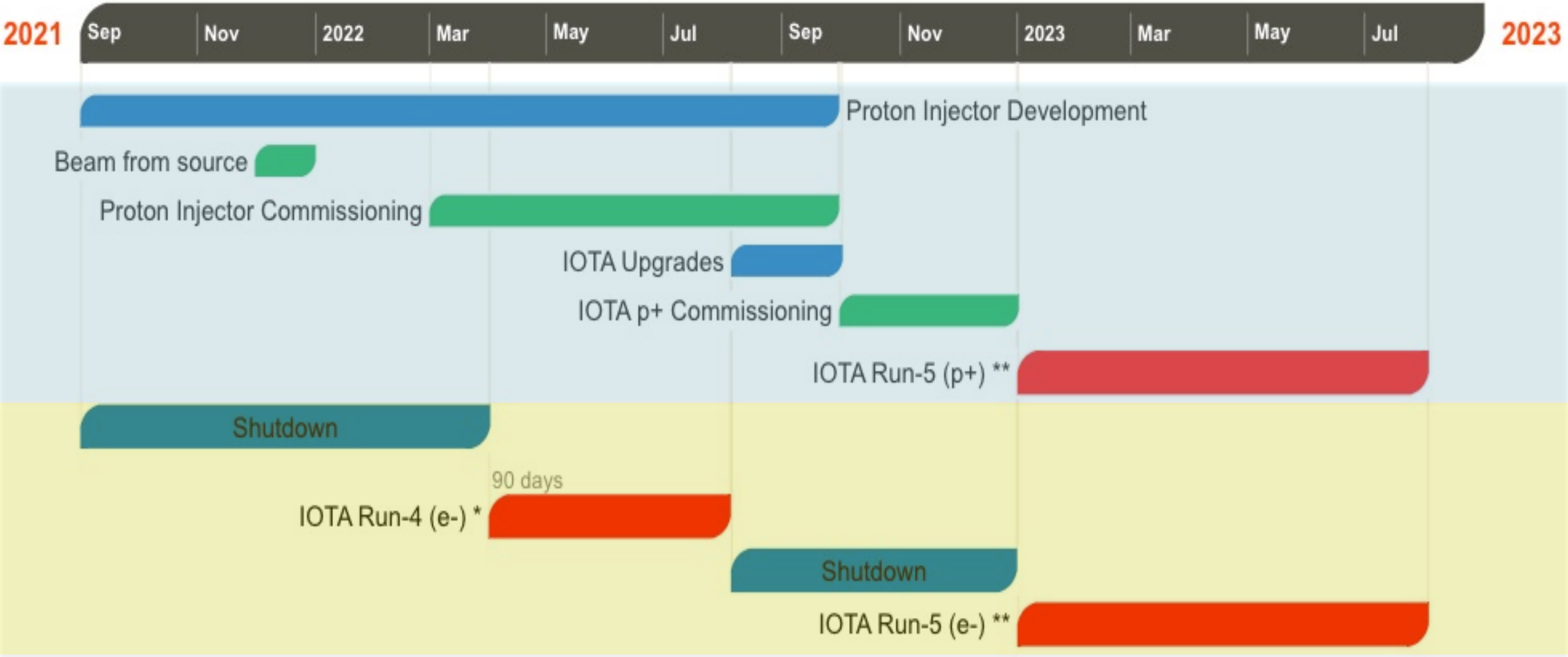
1. Nonlinear Optics Measurements and Correction in the IOTA Ring	PI M.Hofer (R.Tomas), CERN
2. Study of Intrabeam Scattering	V.Lebedev, FNAL
3. Nonlinear Integrable Optics in Run 2	A.Valishev, FNAL
4. Angular Measurement of Photons from Undulator Radiation in IOTA's Single Electron Mode	E.Angelico (H. Frisch/S. Nagaisev), UChicago
5. Measurement of Spontaneous Undulator Radiation Statistics Generated by a Single Electron	S.Nagaitsev, I. Lobach, FNAL/UChicago
6. Fluctuations in undulator radiation	I.Lobach (S. Nagaitsev/G. Stancari), UChicago
7. Instability thresholds and integrable optics	N.Eddy, FNAL
8. Investigations of Long-range and Short-range Wakefield Effects on Beam Dynamics in TESLA-type Superconducting Cavities	A.Lumpkin, FNAL
9. Generation, Transport and Diagnostics of High-charge Magnetized Beams	P.Piot, NIU/ANL

Research in IOTA/FAST Experimental Run 3

Unlike Run-2, the program of Run-3 was focused on OSC. Beam time and resources were allocated to small number of other experiments.

1. Optical Stochastic Cooling Experiment: Apparatus Commissioning	PI J.Jarvs, FNAL
2. Optical Stochastic Cooling Experiment: Demonstration Experiment	J.Jarvis, FNAL
3. Optical Stochastic Cooling Experiment: Systematic Studies of OSC Concepts	J.Jarvis, FNAL
5. Measurement of Spontaneous Undulator Radiation Statistics Generated by a Single Electron	S.Nagaitsev, I. Lobach, FNAL/UChicago
6. Fluctuations in undulator radiation	I.Lobach (S. Nagaitsev/G. Stancari), UChicago
8. Investigations of Long-range and Short-range Wakefield Effects on Beam Dynamics in TESLA-type Superconducting Cavities	A.Lumpkin, FNAL
9. Elegant- and ACL-Based Trajectory Tuning for the FAST Facility	J.Ruan, FNAL

Future Vision



– Run-2 was cut short on March 21, 2020 due to Illinois stay-at-home order. Completion of high-impact NIO research requires e- run

– IPI commissioning can be done in parallel with e- operations

* Run-4 length minimum 3 months

** Run-5 may be separate for e- and p+

Summary

- IOTA/FAST team continues to pursue established goals
  - Development of facility capabilities
  - Execution of experimental program
  - Collaboration and training
- Producing experimental results has been our top priority
  - Nonlinear integrable optics in run-2
  - World's first demonstration of OSC in run-3
  - Excellent results in photon physics, instrumentation, technology
- Team pushes hard to complete two major facility development projects
  - IOTA Proton Injector
  - Electron Lens
- This meeting to foster collaboration and help with development of science program and priorities