Fermilab | U.S. DEPARTMENT OF ENERGY | Office of Science

Research at FAST/IOTA: Strategy and Priorities

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2020 IOTA/FAST Collaboration Meeting

15 June 2020

IOTA/FAST Strategic Goals

- **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

Current 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

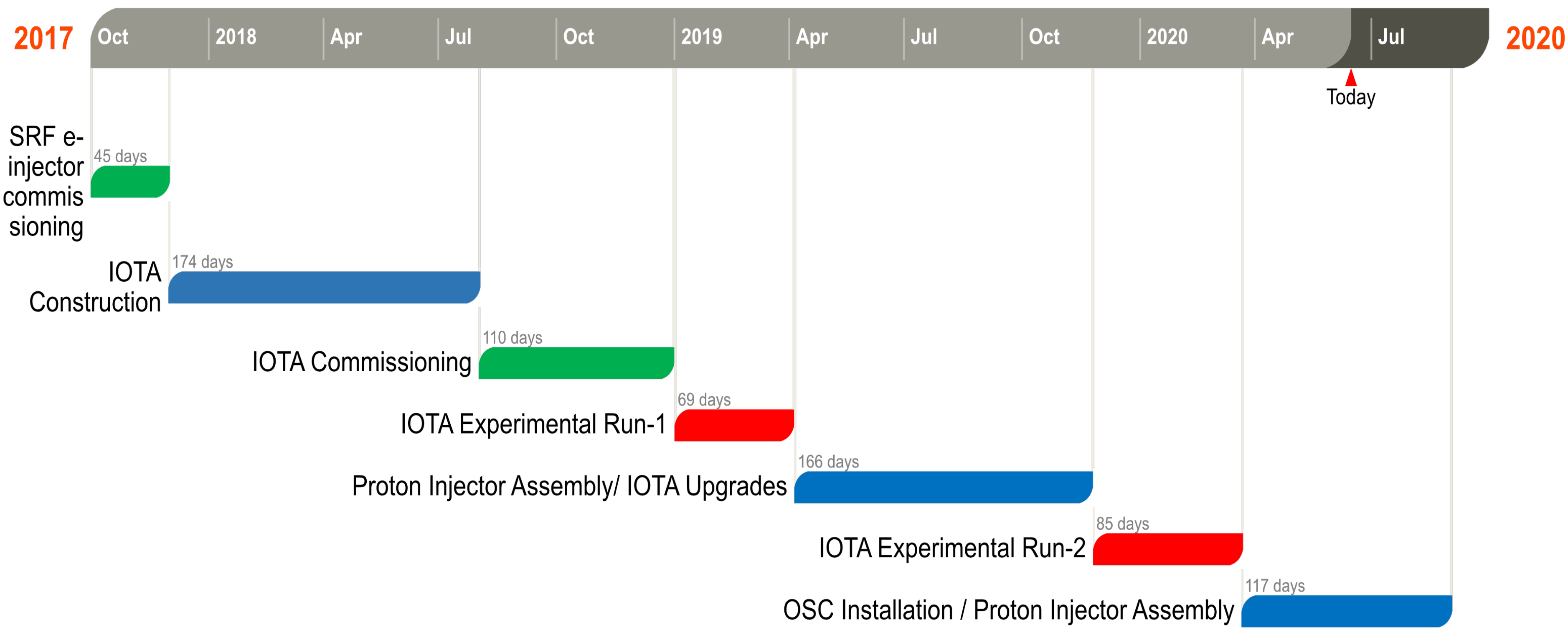
- **Nonlinear Integrable Optics**
  - Can be studied with electrons
  - Several options for implementation: octupole lenses, elliptic-potential magnet, electron lenses
- **Optical Stochastic Cooling**
  - Can do now with electrons
- **Development of novel beam instrumentation**
  - Large dynamic range 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*
- With optical amplifier
  - 2022 and beyond

Transitioning to Stable Research Operation Model

Resources

- Until 2019, most resources were directed to installation and commissioning of IOTA – including the scientific staff
- Some limited resources were dedicated to research
- Transitioning to research-focused model – most resources support research/experimental program
- Established distinct groups for Research and Operations

Beam Operations

- Commissioning dominated operations periods until 2019 (research was parasitic to commissioning) (only operated for 2-4 months at a time)
- Transitioning to 6 months operation per year, 2 shifts/day (use 3rd shift as contingency)

Planning

- Research was and will continue to be dominated by GARD thrusts
- Developing collaborative framework (IOTA/FAST Scientific Committee)

IOTA/FAST Workforce Organization

- FAST Facility Dept – Accelerator development, maintenance and operations
  - Research support personnel
  - **Plan to increase operations staff**
- Accelerator Research Dept – Planning and execution of research program
  - Scientific staff
  - Currently 4 graduate students (3x U.Chicago, 1 NIU)
  - **Plan for more students, postdocs**
- 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

Organization

Accelerator Division

Mike Lindgren, Head

Mary Convery, Deputy

Office of the CRO

Luciano Ristori, CRO

Sergei Nagaitsev, Head of Accel Science Programs

AD Accelerator S&T sector

A. Valishev, Head
(S. Nagaitsev), Accel. science lead

FAST Facility Dept.

D.Broemmelsiek, Head

Develop, operate, maintain FAST facility

Support the IOTA/FAST experimental program

Accelerator Research Dept.

G.Stancari, Head

Develop and carry out IOTA/FAST experimental program

Accelerator Physics Support Dept.

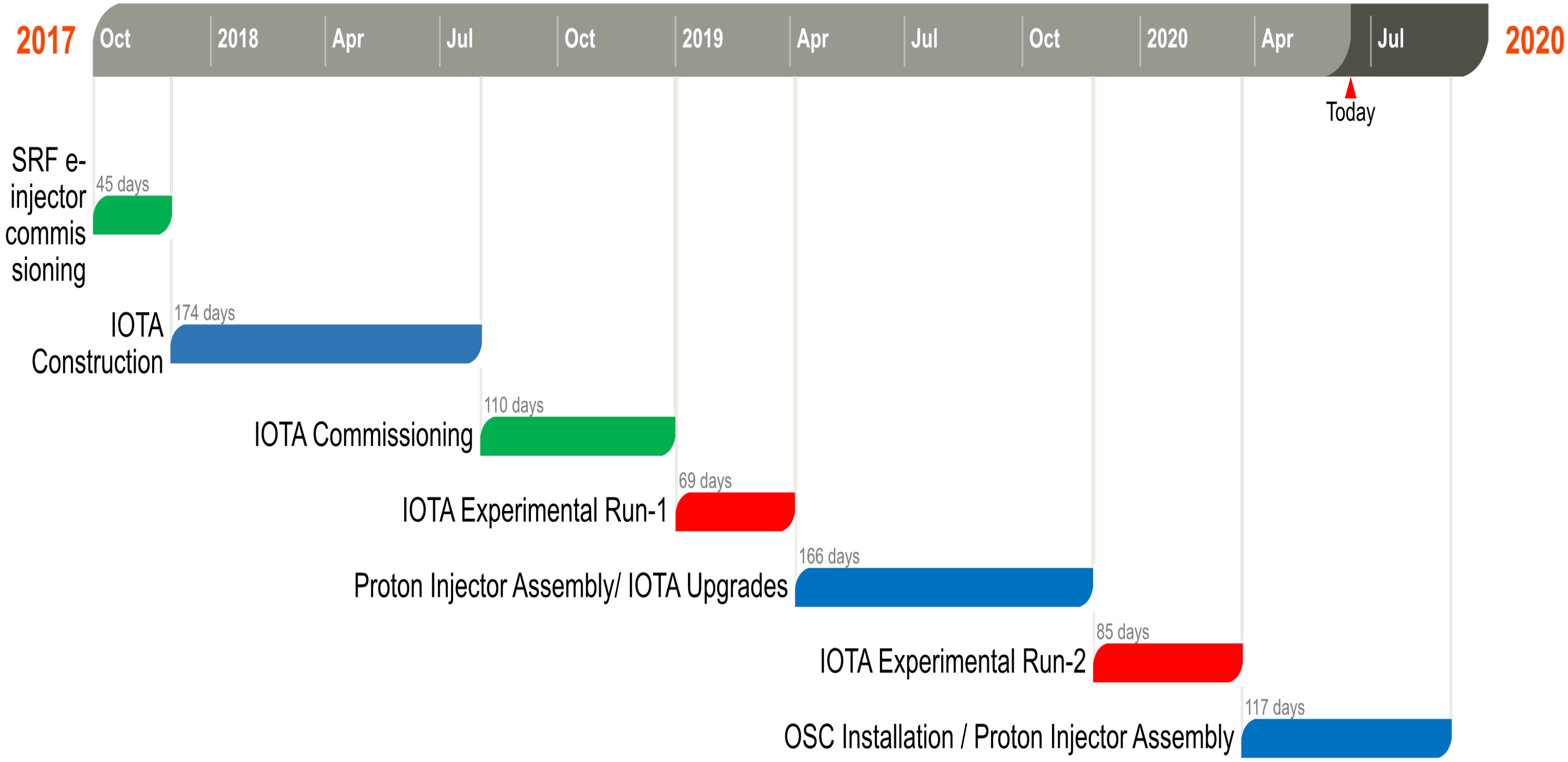
R&D in support of Fermilab's complex operations

R&D for future facilities

Accelerator Education

PhD program
Summer internships
USPAS

IOTA/FAST Recent Timeline



Research in IOTA/FAST Experimental Run 2

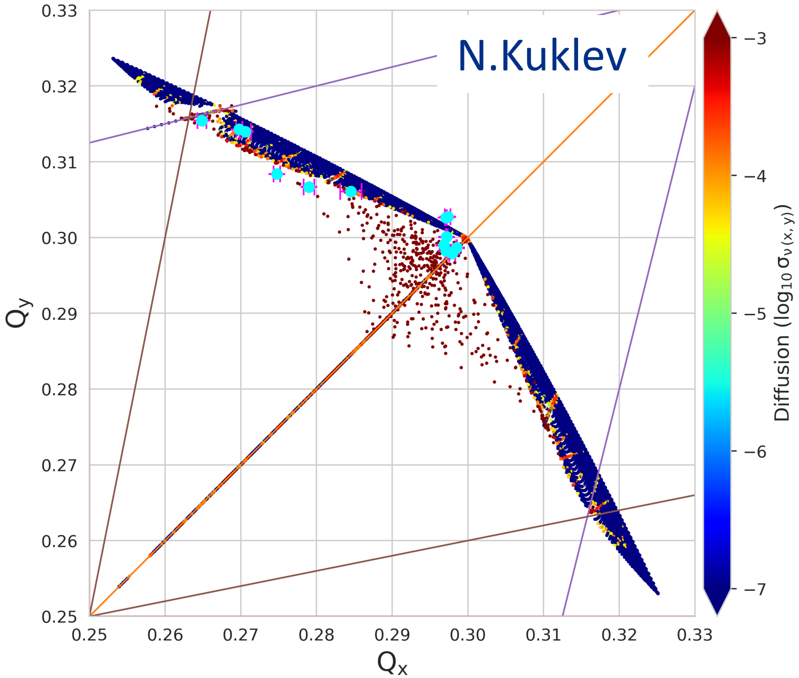
Broad program: in all 9 experiments took data over 60 shifts and produced relevant results. Engagement of outside collaborators (CERN, SLAC, Jlab, Uchicago, NIU) and 6 graduate students.

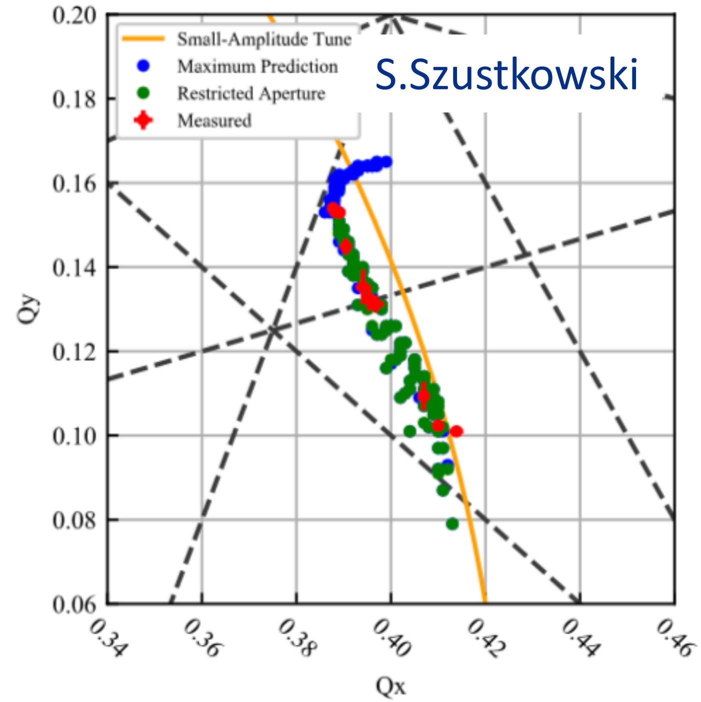
1. Nonlinear Optics Measurements and Correction in the IOTA Ring	PI M.Hofer (R.Tomas), CERN
2. Study of Intrabeam Scattering	V.Lebedev, FNAL
3. Nonlinear Integrable Optics in Run 2	A.Valishev, FNAL
4. Angular Measurement of Photons from Undulator Radiation in IOTA's Single Electron Mode	E.Angelico (H. 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

Highlighted Accomplishments

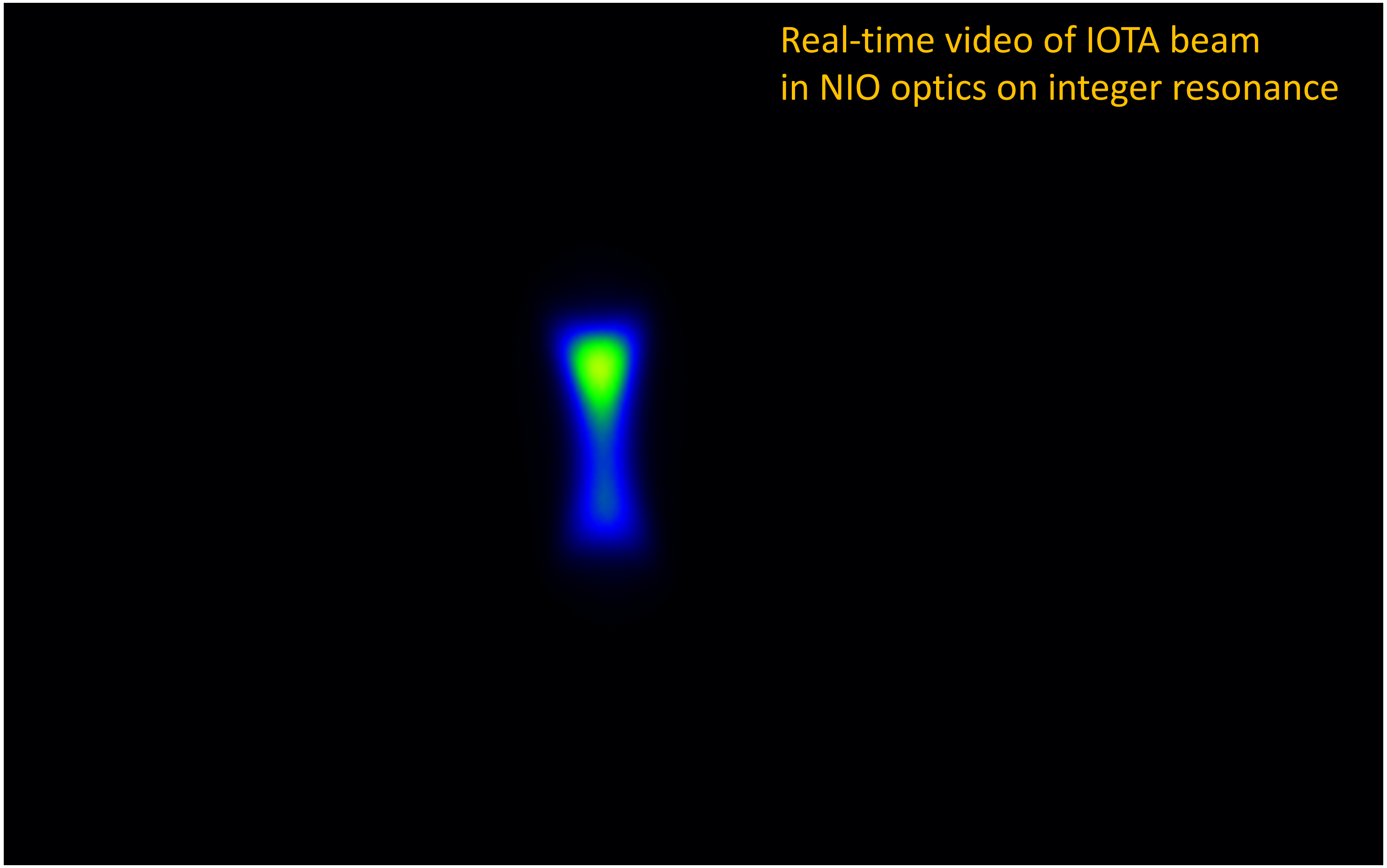
Run-1 Results – Amplitude-Dependent Tune Shift

- ~60-70% of ideal performance for both types of NIO
- Clear improvement vs single octupole
- Improvements in Run-2

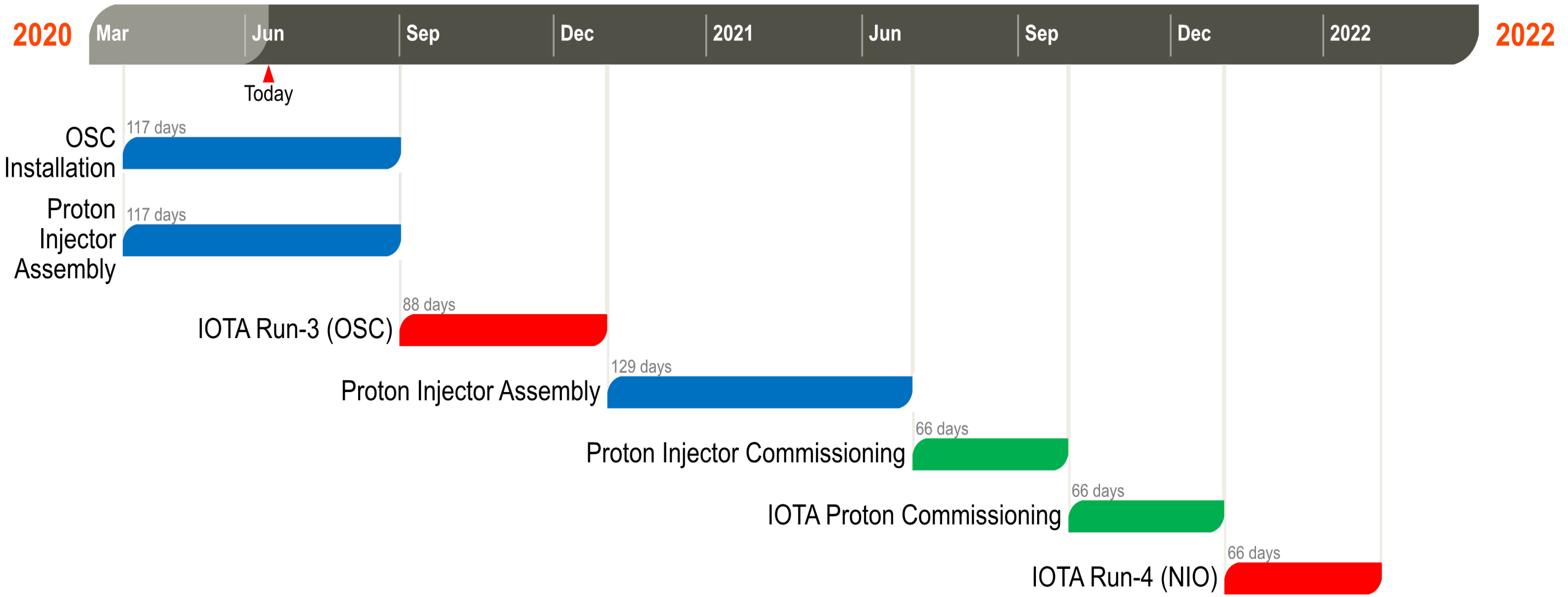




Run-2 Highlight – Beam on Integer !!!



Future Vision



IOTA/FAST schedule was and continues to be impacted by covid-19

- Run-2 was cut short on March 21, 2020 due to Illinois stay-at-home order
- OSC installation and Proton Injector work was stalled until June
- Slow recovery

Summary

- IOTA/FAST has a very strong research portfolio addressing both medium and long-term mission of accelerator science
- Short term goals are well defined, and priorities established based on the available resources and science impact
- We have a very strong and focused team
- Call to the collaboration to strengthen the research and develop long-term vision and path for FAST