IOTA/FAST Scientific Program:
Intro to 2016 Meeting, Status, Progress, Plans

Vladimir SHILTSEV, Accelerator Physics Center/AD
IOTA/FAST Scientific Program Meeting
June 14, 2016
Key points on the Intensity Frontier HEP:

- "CP-violation sensitivity" → need $900 \text{ kt} \times \text{MW} \times \text{yrs}$

- **R12**: build LBNF/DUNE 40 kt LAr
  - Then 400kW → >50 years to get $900 \text{ kt} \times \text{MW} \times \text{yrs}$

- **R14**: build PIP-II linac to get >1 MW
  - current plan 40 kt × 1 MW × 5 yrs = > $200 \text{ kt} \times \text{MW} \times \text{yrs}$

- **R23/26**: accelerator R&D (facilities) toward multi-MW
  - say, 40 kt × 2.5 MW × 7 yrs = remaining $700 \text{ kt} \times \text{MW} \times \text{yrs}$
Intensity Frontier HEP Accelerators

- 300+ kW  JPARC (Japan)
- 400+ kW  CNGS (CERN)
- 600+ kW  Fermilab’s Main Injector (2016)
- 700+ kW  Proton Improvement Plan (PIP, 2016)
- 1.2+ MW  Proton Improvement Plan-II (ca 2025)
- 2.5 MW
- 5 MW?

Challenges → need R&D @ Beam Facilities

Post Plan-II multi-MW Upgrade (under study)
Post PIP-II multi-MW Upgrade = Replace Booster

Cost-effective options:

- **RCS:** with improved performance beyond current by a factor of 2-4:
  - e.g. \( dQ_{sc} > 1 \) (vs \( \sim 0.25-0.3 \) now)
  - Therefore, FAST/IOTA facility and R&D

- **Linac:**
  - SRF R&D towards better performance and lower cost

* Note: technologies of today exist, just costly (JPARC-like RCS, Project X SRF)
To enable multi-MW beam power, losses must be kept well <0.1% at the record high intensity:

- Need <0.06% for the post PIP-II ~2.5 MW upgrade
- Present level ~3-5% in Booster and MI synchrotrons
- (Very challenging after 50 years of development)

Need to develop tools for

- Space-charge countermeasures
- Beam halo control
- Single-particle and coherent beam stability
• **Recommendation 2:** Construct the IOTA ring, and conduct experimental studies of high-current beam dynamics in integrable non-linear focusing systems. (p. 9, 18)
  - GARD thrust: Accelerator and Beam Physics

• **Recommendation 3:** Support a collaborative framework among laboratories and universities that assures sufficient support *in beam simulations and in beam instrumentation to address beam and particle stability including strong space charge forces.* (p. 9, 17)
  - GARD thrust: Accelerator and Beam Physics
FAST/IOTA in NML: Definitions

- FAST/IOTA is Accelerator R&D Facility that consists of:
  - IOTA ring itself
  - Its two injectors = FAST (Fermilab Accelerator Science and Technology) facility
  - Both occupy the 18,000 sq ft NML facility building

- IOTA/FAST supported by:
  - HEP GARD: construction, installation, research
  - HEP Test Facilities Ops: accelerator operations, NML building
  - Collaborators: components, research
FAST/IOTA Program Organization

**S. Nagaitsev**
Chief Accelerator Officer

**V. Shiltsev, APC**
FAST/IOTA Program Director

**Construction and Operations**

**J. Leibfritz, MS**
Construction
Installation, Engin’ng
Facility Operations

**E. Harms**
SRF Installation
SRF Commissioning

**A. Valishev, APC**
IOTA Construction
Commissioning
Beam Operations

**D. Broemmelsiek**
Beam Operations
Beam Commissioning

**E. Prebys, APC**
RFQ Re-Commiss’ing
RFQ Relocation

**Beam Physics Research**

**A. Valishev, APC**
Integrity Frontier Exp’s
Space-Charge Collab’n

**A. Valishev, APC**
Integrable Optics experiments (e-/p+)

**G. Stancari, APC**
e-lens program, Space-Charge Compensation

**S. Chattopadhyay, NIU**
Advanced Physics Exp’s
University Collaborations
International Collaborations

**Opt. Stoch. Cooling**
(V. Lebedev, et. al)
Single e- Correl.
(Swapan C., et. al)
Channeling X-ray
(P. Piot, et. al)
other experiments
IOTA Experiments: Intensity Frontier Scirnce

- **E1.1-1.3: Integrable Optics**
  - #1: IO with non-linear magnets, tests with electrons
    - PIs: Valishev, Nagaitsev
  - #2: IO with non-linear magnets, tests with protons
    - PIs: Valishev, Prebys
  - #3: IO with e-lens(es), tests with protons
    - PIs: Stancari, Valishev

- **E1.4-1.6: Space-Charge Compensation & Studies**
  - #4: SCC with e-lens(es), tests with protons
    - PIs: Stancari, Shiltsev
  - #5: SCC with e-columns, tests protons
    - PIs: Shiltsev, Thangaraj
  - #6: General SC studies with protons (vs $P, Q, Q'$, optics errors, etc)
    - PIs: ???
FAST/IOTA Exp’s: Accelerator & Beam Physics

**E2.1-2.5:**

- #1: X-ray crystal radiator
  - **PIs:** Piot
- #2: Optical Stochastic Cooling
  - **PIs:** Lebedev
- #3: Single electron quantum optics
  - **PIs:** Dixon
- #4: Beam optics of SRF cavities
  - **PIs:** Piot
- #5: Laser-plasma e- injector to IOTA
  - **PIs:** Romanov, ?
June 2015 : Renaming ASTA → FAST

Subject: FAST Facility Announcement

To: beamsdivlst@listserv.fnal.gov, Nigel S. Lockyer, T 13 more
Cc: Hema Ramamoorthi, Stephany Unruh

Please see following message from Sergei Nagaitsev.

Dear Colleagues,

I am writing today to introduce a new name to describe one of our accelerator R&D and test facilities.

The FAST (Fermilab Accelerator Science and Technology) Facility encompasses the R&D and test infrastructure that is presently located in the New Muon Lab building and its recently constructed extension.

FAST consists of:
1. The IOTA ring (a storage ring for experimental research with electrons and protons)
2. An electron injector (a 300-MeV SRF-based photo injector)
3. A proton injector (a conventional ion source followed by a 2.5-MeV RFQ)
4. All associated conventional, rf and cryo infrastructure presently housed in the New Muon Lab and its extension.

The FAST Facility's mission is to provide the test infrastructure critical to the research and development of future accelerators for the US HEP community as well as for our university, international, and commercial partners.

(S. Nagaitsev, FNAL, AD Head)
Dec. 2015: Briefing OHEP on GARD at IOTA/FAST

- One day meeting in Germantown:
  - Dec. 17
  - To report technical progress and plans
  - For all GARD “thrusts”
  - Based on “realistic” budget as communicated to/agreed with DOE OHEP for FY16-18
  - For FAST/IOTA: “resource-loaded” plan for construction, commission and research

- (Overall conclusion – positive)
## IOTA Construction and Research Timeline

<table>
<thead>
<tr>
<th></th>
<th>Electron Injector</th>
<th>Proton Injector</th>
<th>IOTA Ring</th>
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<tbody>
<tr>
<td>FY15</td>
<td>20 MeV e- commiss’d beam tests</td>
<td>Re-assembly began @MDB</td>
<td>50% IOTA parts ready</td>
</tr>
<tr>
<td>FY16</td>
<td>50 MeV e- commiss’d beam tests</td>
<td>50 keV p+ commiss’d</td>
<td>IOTA parts 80+% ready</td>
</tr>
<tr>
<td>FY17</td>
<td>150-300 MeV e- beam commissioning/tests*</td>
<td>2.5 MeV p+ commiss’d beam tests @ MDB</td>
<td>IOTA fully installed first beam ? *</td>
</tr>
<tr>
<td>FY18</td>
<td>e- injector for IOTA + other research</td>
<td>p+ RFQ moved from MDB to FAST *</td>
<td>IOTA commiss’d with e- Research starts (NL IO)</td>
</tr>
<tr>
<td>FY19</td>
<td>e- injector for IOTA + other research</td>
<td>2.5 MeV p+ commiss’d beam tests</td>
<td>IOTA research with e- IOTA commiss’d with p+</td>
</tr>
<tr>
<td>FY20</td>
<td>e- injector for IOTA + other research</td>
<td>p+ injector for IOTA</td>
<td>IOTA research with p+*</td>
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</table>

*beam operations

- contingent on $$: FY17-20 - under current budget scenario...together with OHEP GARD management we explore options to accelerate start of research by 1 year (1.48M$ supplemental)
May 16, 2016: Beam accelerated by both Capture Cavities #1 and #2: 4.5 MeV (gun)+28MeV+20MeV

52.5 MeV $e^-$ beam through FAST injector!
May 16, 2016: “Both CC’s work, beam thru!”
Review of the FAST/IOTA “Facilities Operations” KA250201

Jerry Leibfritz tours the Review committee (G.Neil, S.Prestemon, K.Jones, LK Len, B.Strauss) – in FAST
(general comments)

- The Accelerator Test Facility infrastructure at FNAL is a national (and international) resource with many unique capabilities, and OHEP is the nominal steward of these facilities.

- Generally well aligned with P5. Very systematic and dogmatic in this area.

- **(comment)** Operations cost for FAST/IOTA will need to increase as the facility comes online. This increase cannot come at the expense of other test facilities in the same B&R code without significant impact to ongoing projects/programs, as their scope is independent.

**Recommendations:**

(none for FAST/IOTA)
May 21, 2016: Fermilab Director Nigel Lockyer visits FAST

05-21-2016 - Nigel Lockyer visited on 05-20-2016.

Dear Vladimir and FAST Team Members,
Thank you for your time yesterday. It is obvious a lot of work has gone into getting the facility to this point. It was a pleasure to meet our first experiment student, Alexei, good luck with getting all those guys to work for you! I am also glad that I could help you turn the machine back on.

FAST represents the beginning of a new era at Fermilab where accelerator science becomes an important and productive part of the laboratory program. Keep up the good work. Everyone will notice.

Thank you again,
Nigel
June, 2016: In the news  http://news.fnal.gov

New beginning at FAST: Research accelerator reaches design beam energy

June 8, 2016  |  Leah Hesla

On May 16, Fermilab sent an electron beam with an energy of 50 million electronvolts, or MeV, through the photoinjector at the Fermilab Accelerator Science and Technology facility (FAST), achieving a major design goal for the accelerator – and marking the beginning of a new accelerator science program at the laboratory.

“This is a major milestone for our general accelerator R&D,” said Vladimir Shiltsev, head of the Fermilab Accelerator Physics Center. “The delivery of this beam marks the start of a new program here – new facility, new science capabilities,” Shiltsev said.

The delivery of 50-MeV beam is the first step in establishing an accelerator R&D facility that will serve as one of America’s leading test beds for cutting-edge, record-high-intensity particle beam research. Once complete, FAST will provide scientists and engineers from around the world with a place to study the science of high-intensity particle beams and superconducting radio-frequency acceleration, the technology on which nearly
Today: Collaboration’s 4th Annual Meeting

- **25 Partners:**

- **NIU-FNAL:** Joint R&D Cluster

- Publications, presentations at conferences, workshops, etc
Students at IOTA/FAST

2015 Graduates

Sriharsha Panuganti
PhD
NIU

Frederic Lemery
PhD
NIU

David P. Lopez
MSci
Universidad de Guanajuato
(Mexico)
DOE Early Career Research Proposals

2016 Award

Chad Mitchell –
our collaborator from the Lawrence Berkeley National Laboratory, Berkeley, CA - selected by the Office of High Energy Physics for the Early Career Research Proposal award “Compensation of Nonlinear Space Charge Effects for Intense Beams in Accelerator Lattices”
IOTA/FAST Program Support

- Construction/installation: GARD (HEP)
- Operations: Acc.Test.Facility (HEP)
- Research:
  - GARD (HEP) “Accelerator & Beam Physics” thrust
  - NSF Accel. Sci. program
  - Early Career Awards
  - LDRD
  - SBIRs
  - Lab’s/University grants

We are trying to help all collaborators to get support (letters, etc)
This Meeting (4th in Series) is to:

- Review the status of the facility
- Share the results of the first studies and tests
- Evaluate the progress toward key advanced beam physics experiments at IOTA
- Further develop the scientific program of the facility with full synergistic support from the community
- Help and enhance the national and international developments collaboratively to ensure the success of the program.

- There will be a tour of the New Muon Lab after the meeting.
- You are also invited to attend the Festa Italiana event held tonight 8pm - 11pm at the Kuhn Barn - in the Village
- Tomorrow, “big” Fermilab Users Meeting
Back up slides