Electron lens for the Fermilab Integrable Optics Test Accelerator (IOTA)

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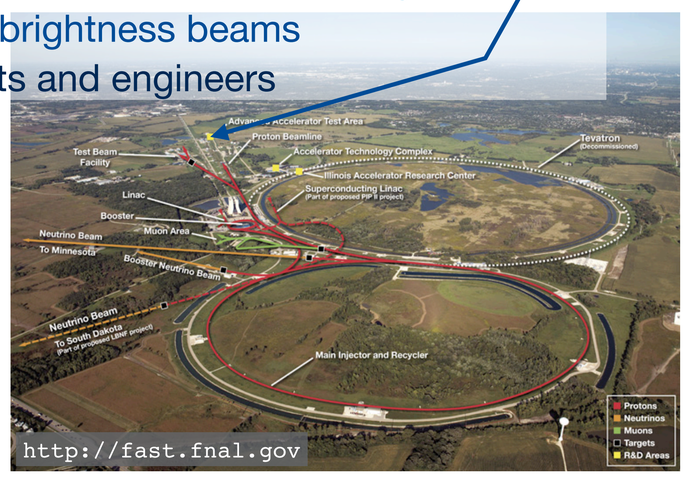
Fermilab Accelerator Science and Technology (FAST) facility

- develop high-intensity accelerators for particle physics
- study the physics of high-brightness beams
- educate and train scientists and engineers



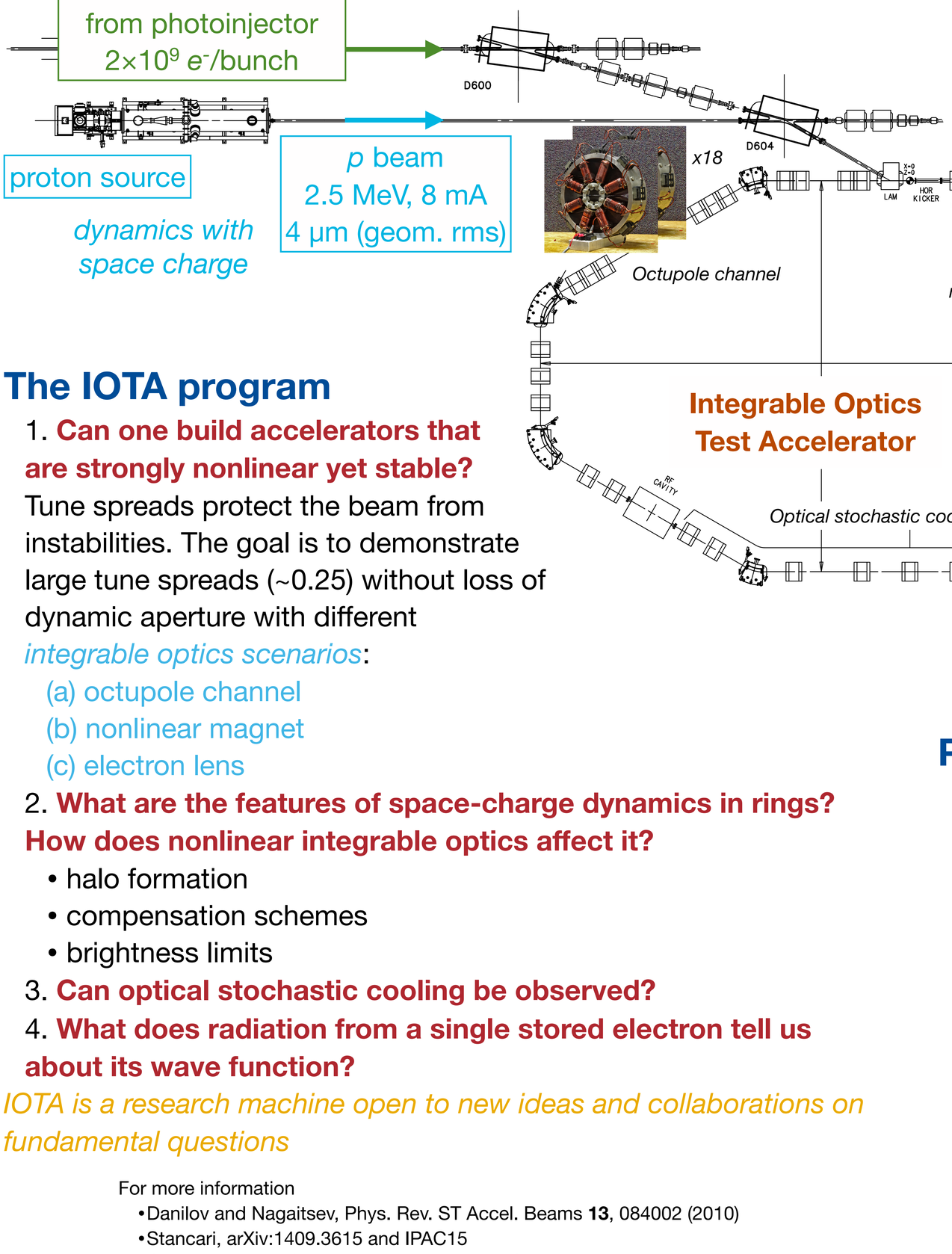
single-particle dynamics with pencil beams

50-300 MeV electrons from photoinjector
2×10^9 e^-/bunch

proton source

p beam
2.5 MeV, 8 mA
4 μm (geom. rms)

dynamics with space charge



What is an electron lens?

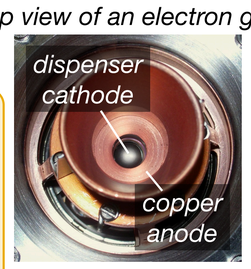
An electron lens is a **low-energy, magnetically confined, pulsed electron beam** used to actively manipulate the dynamics of the circulating beam in storage rings and colliders. Main features:

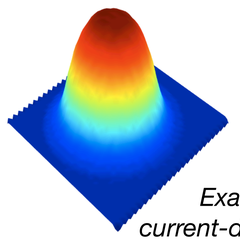
- variable **current-density profile** to shape fields and kicks
- flexible **time structure** of the pulse

Purposes of IOTA electron lens

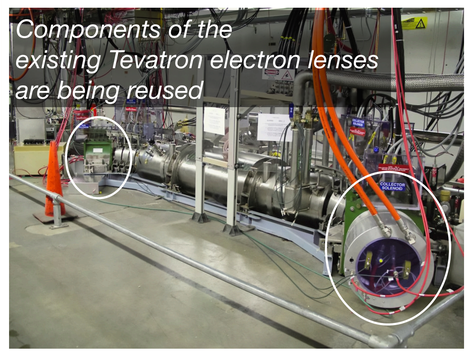
- **Nonlinear integrable optics element**
  - axially symmetrical thick lens, constant beta function OR
  - thin McMillan lens
- **Electron cooler for protons**
  - explore brightness limits with nonlinear integrable optics
  - expand range of space-charge experiments
  - provide profile measurements through recombination
- **Trap and measure electron column** from residual gas for space-charge compensation

Top view of an electron gun





Example of current-density profile



The IOTA program

1. **Can one build accelerators that are strongly nonlinear yet stable?**
   Tune spreads protect the beam from instabilities. The goal is to demonstrate large tune spreads (~0.25) without loss of dynamic aperture with different *integrable optics scenarios*:
   (a) octupole channel
   (b) nonlinear magnet
   (c) electron lens
2. **What are the features of space-charge dynamics in rings? How does nonlinear integrable optics affect it?**
   - halo formation
   - compensation schemes
   - brightness limits
3. **Can optical stochastic cooling be observed?**
4. **What does radiation from a single stored electron tell us about its wave function?**

IOTA is a research machine open to new ideas and collaborations on fundamental questions

Plans

- 2016–2017
  - complete photoinjector and electron linac
  - start research program with injector
  - build IOTA
  - commission proton injector
  - commission IOTA with electrons
  - measure single-particle dynamics with electrons
- 2018–2020
  - commission IOTA with protons
  - begin experiments with space charge
- 2021—
  - apply results to next generation of high-intensity machines
  - expand program to serve accelerator and particle physics communities

For more information
- Danilov and Nagaitsev, Phys. Rev. ST Accel. Beams **13**, 084002 (2010)
- Stancari, arXiv:1409.3615 and IPAC15
- Contributions of Cook, Nagaitsev, Ruisard, Stem, and Webb at this workshop
- Pinayev et al., Nucl. Instrum. Methods Phys. Res. A **341**, 17 (1994)

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