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Northern Illinois Center for Accelerator and Detector Development

NIU

Magnetized-Beam Formation and Beam-Beam Kicker for Electron Cooling

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JLEIC Collaboration Meeting
Spring 2017
Jefferson Lab • April 3 - 5, 2017

Outline

- Introduction
- Formation & manipulation of magnetized beam
- Beam-beam kicker
- Outlook & plans

Introduction

- This talk discusses **interests** from our group to carry work related to JLEIC electron cooling

- Over the last 3 years we have submitted five proposals
  - 3 STTRs (1 reviewed but denied funding, 2 returned without review – **deemed unresponsive**…)
  - 2 unfunded university proposals to DOE NP

- The following slides are essentially *exploratory work* done in preparation of these proposals and related to synergistic work funded by other sources.

High-Current Magnetized-beam R&D

- Two directions
- Simulations:
  - Beam dynamics
  - Emission process
- Experiments:
  - At Fermilab FAST/IOTA facility, Argonne Wakefield Accelerator (AWA), and using a standalone DC gun at NIU.

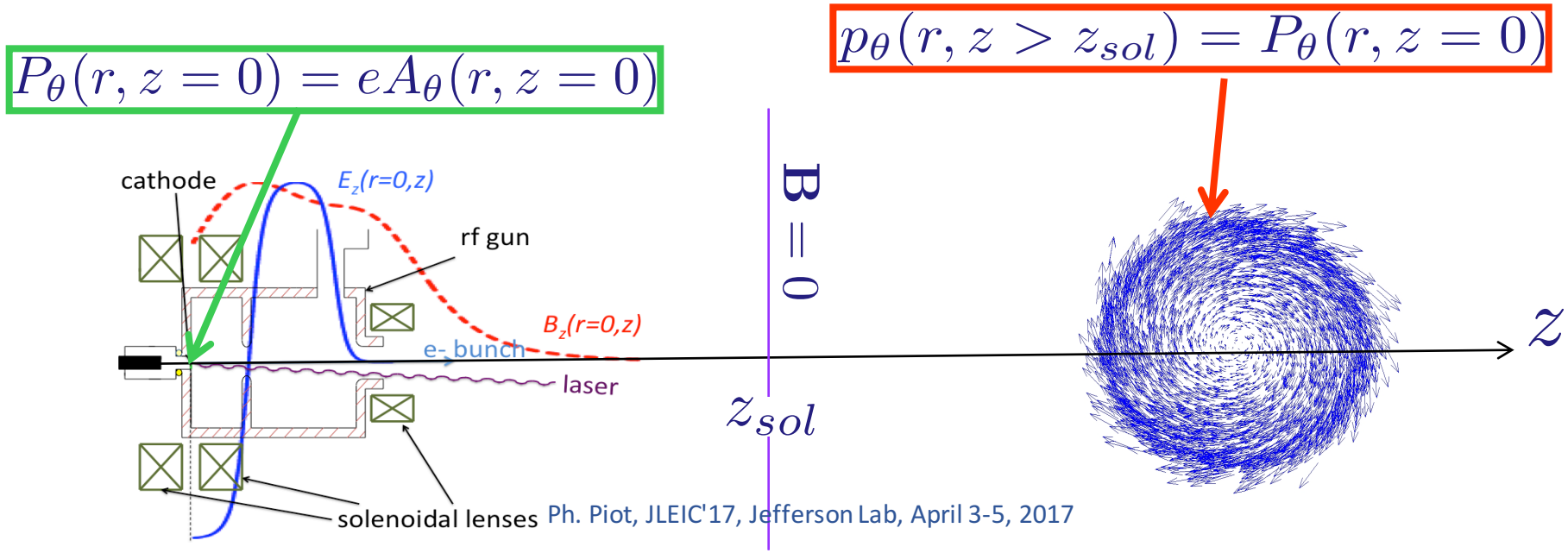
- **Photoemission sources:**
  - Demonstrate single-bunch performance
  - Explore scaling,
  - Investigate new concept,
  - Develop relevant diagnostics
  - Temporal shaping for flat-top e- beam
- **Development of a high-current gun based on alternative emission mechanism:**
  - Thermionic emission
  - Field-emission

Magnetized beam formation: basics

- electrons born in an axial B field $B_z \rightarrow$ CAM

$$L(r) = erA_\theta \simeq \frac{er^2}{2} B_{z,0} + \mathcal{O}(r^4)$$

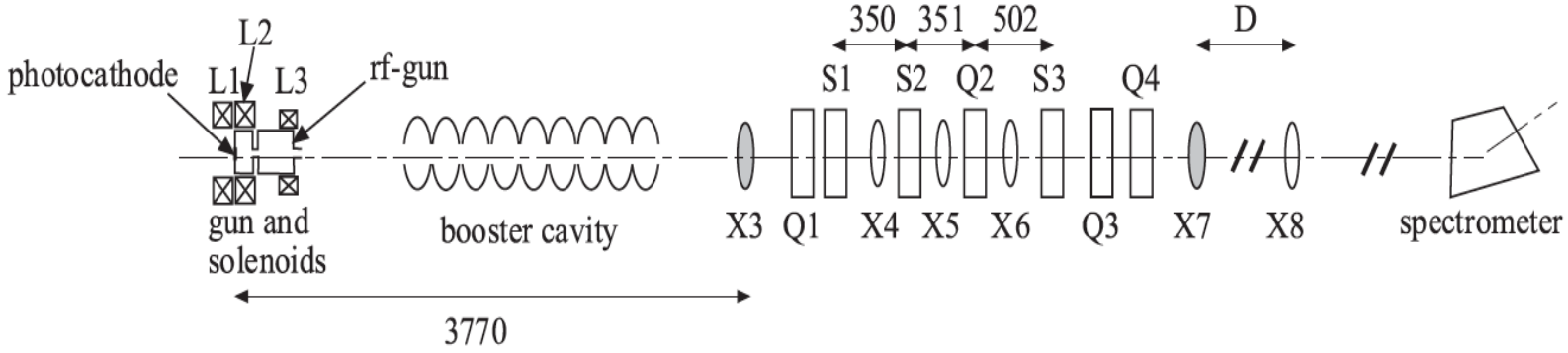
- upon exit of solenoid field ($A_\theta = 0$): CAM becomes purely kinetic.

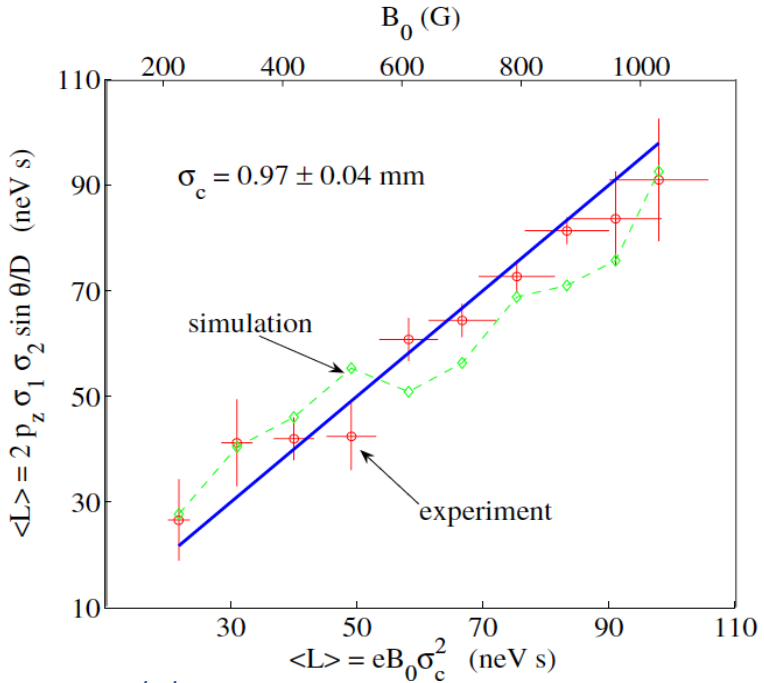


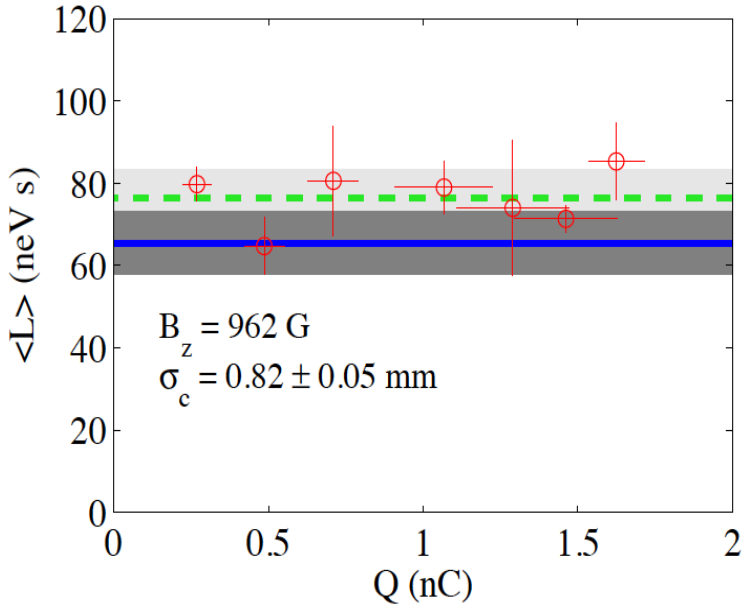
Y.-E Sun et al, PRSTAB 7, 123501 (2004)

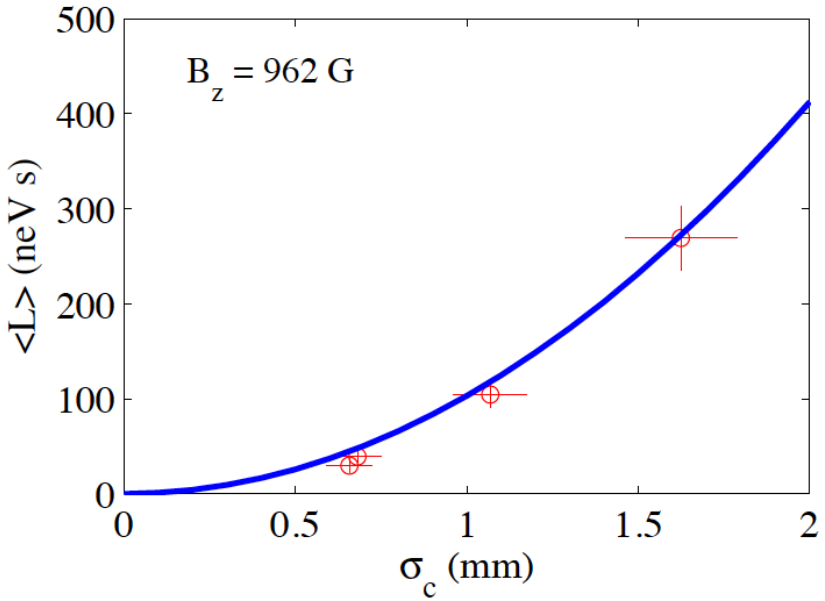
Previous work in an RF photoinjector (A0PI)

- Weak Q dependence,
- quadratic scaling with laser spot size σ_c on photocathode.





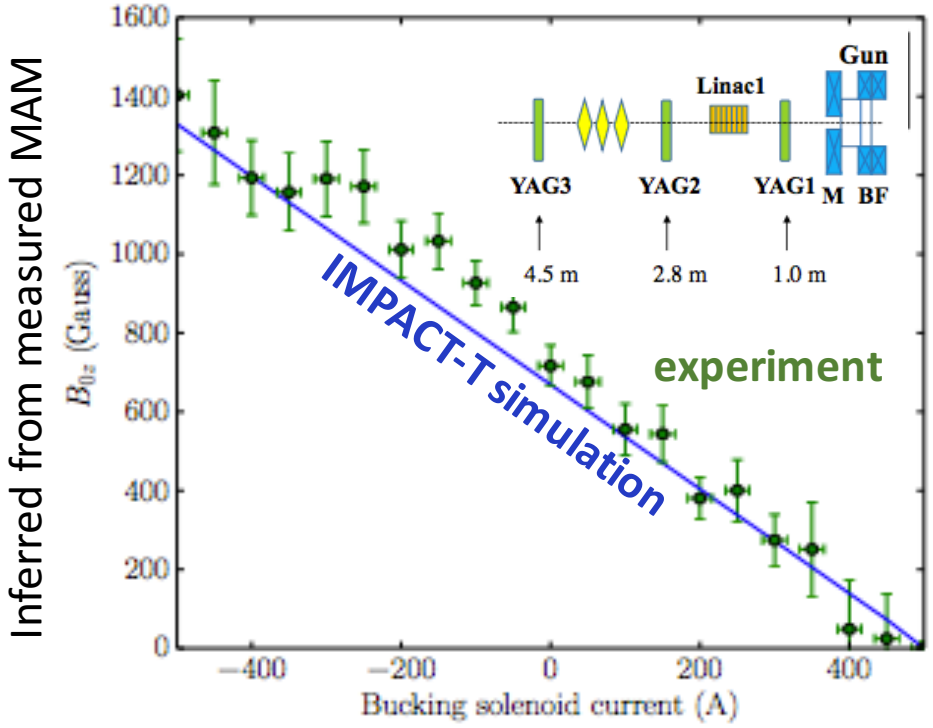


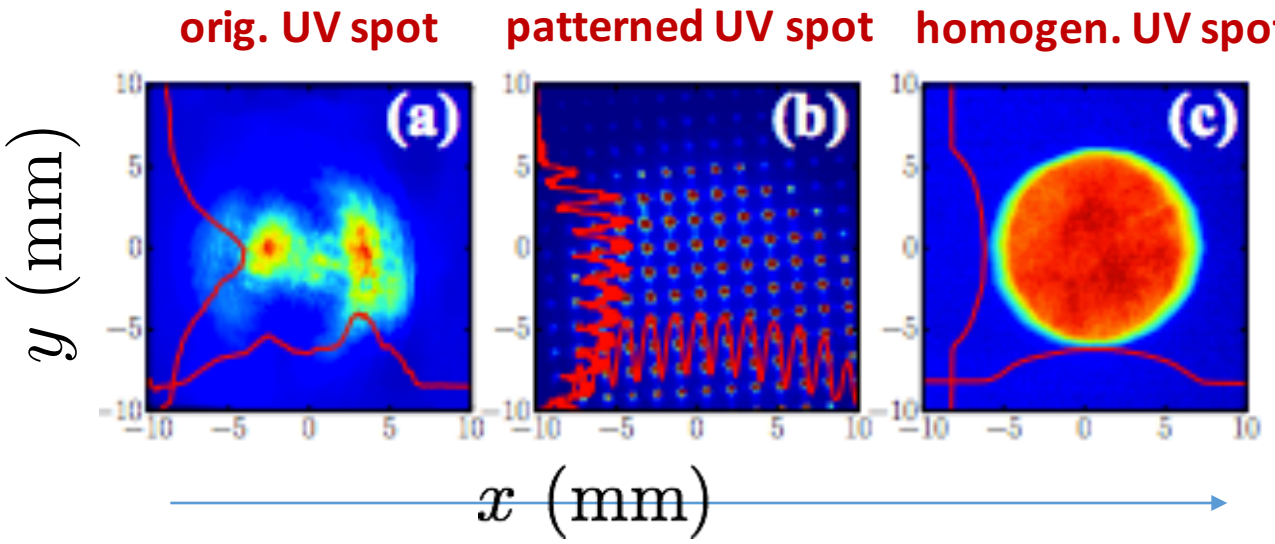


A. Halavanau et al, in preparation (2017);
see also arXiv:1609.01661 [physics.acc-ph]

On-going work in collaboration w. AWA (Argonne)

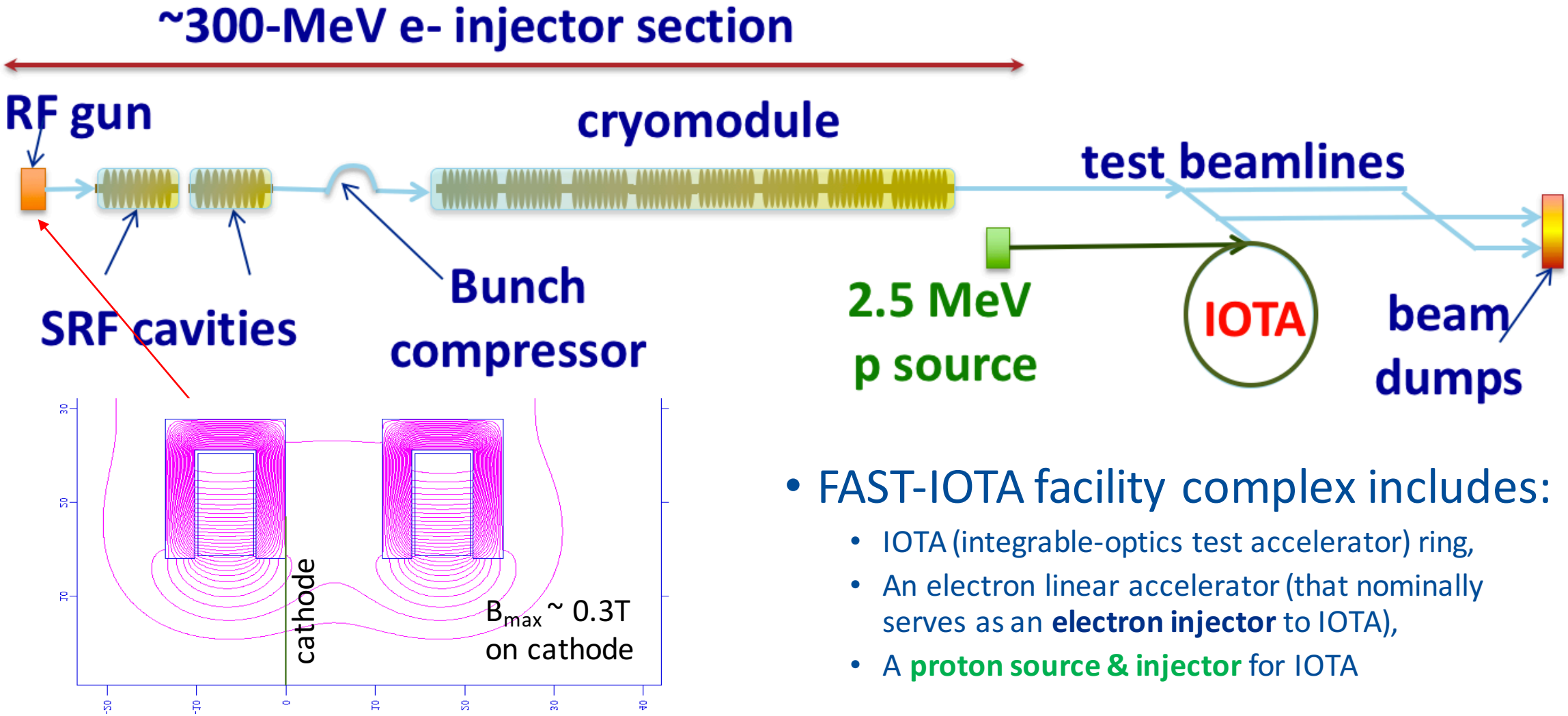
- Generation of very uniform laser spots on photocathode using a microlens array (MLA)





- Production of multi-beam pattern at AWA witness beamline → could help understand the non-paraxial depen-dence of the CAM

Planned experiment at FAST/IOTA

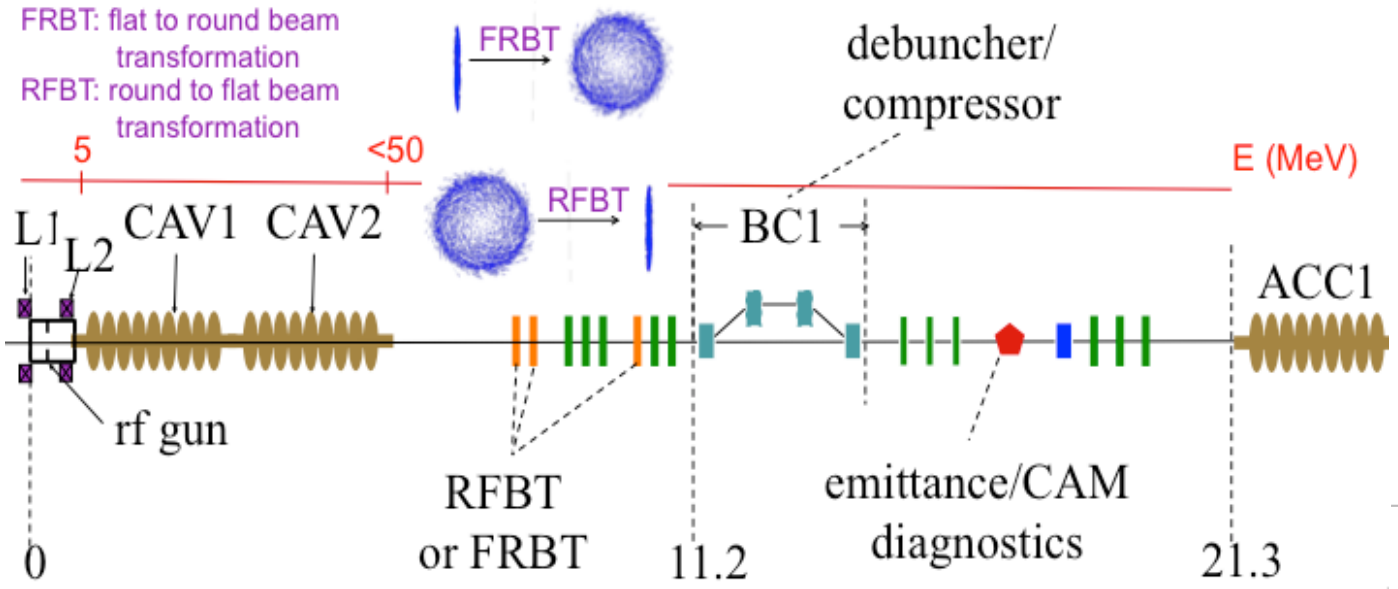


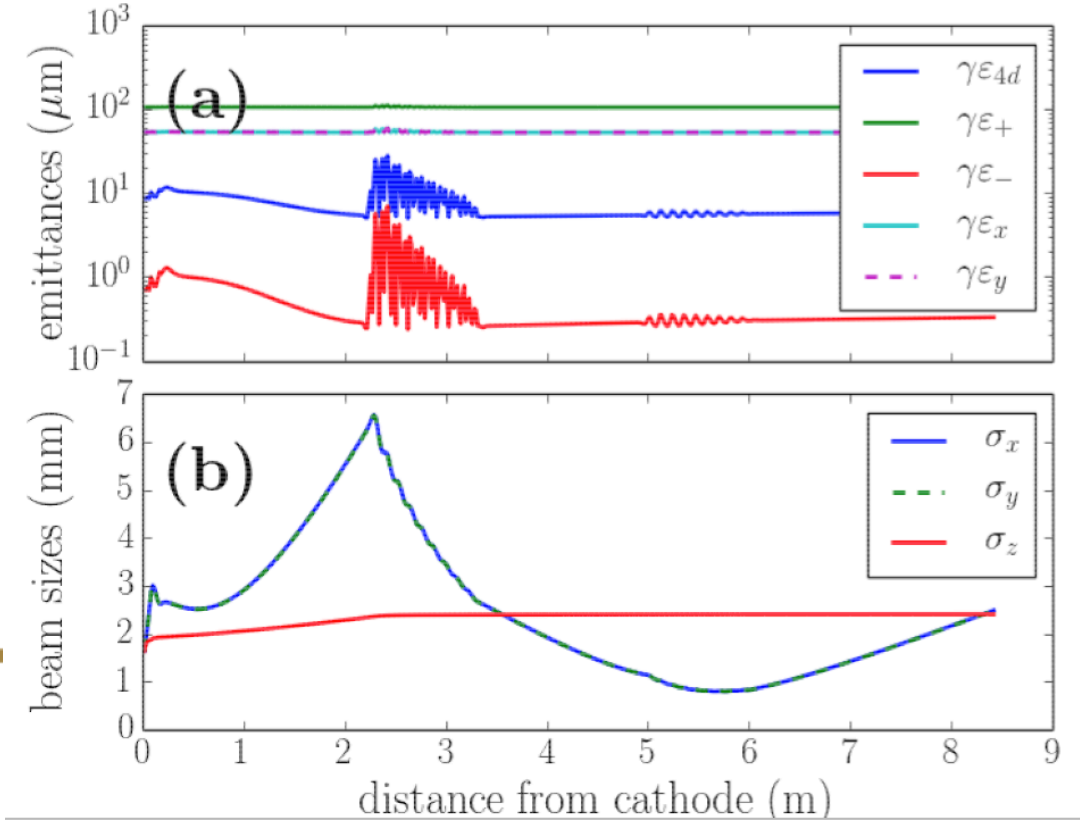
- FAST-IOTA facility complex includes:
  - IOTA (integrable-optics test accelerator) ring,
  - An electron linear accelerator (that nominally serves as an **electron injector** to IOTA),
  - A **proton source & injector** for IOTA

P. Piot, IPAC13 (2013)
J. Zhu, et al. PRSTAB 17, 084401 (2014)

Planned experiments at FAST/IOTA (Summer 17)

- Experiment to focus on flat beam generation (after decoupling of magnetized beam with a skew-quad channel
- Characterization of magnetized beams will be a byproduct

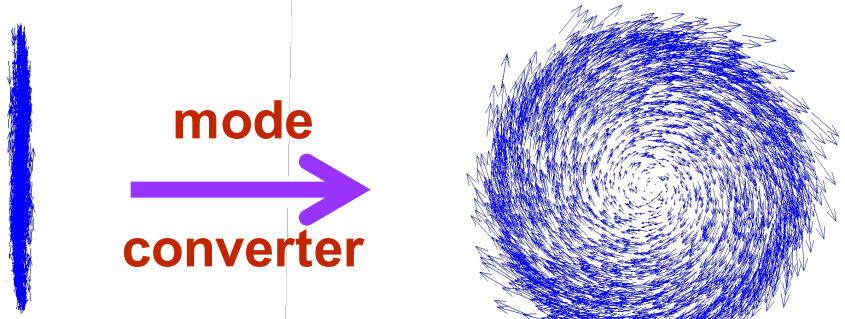




P. Piot, to be presented at IPAC17

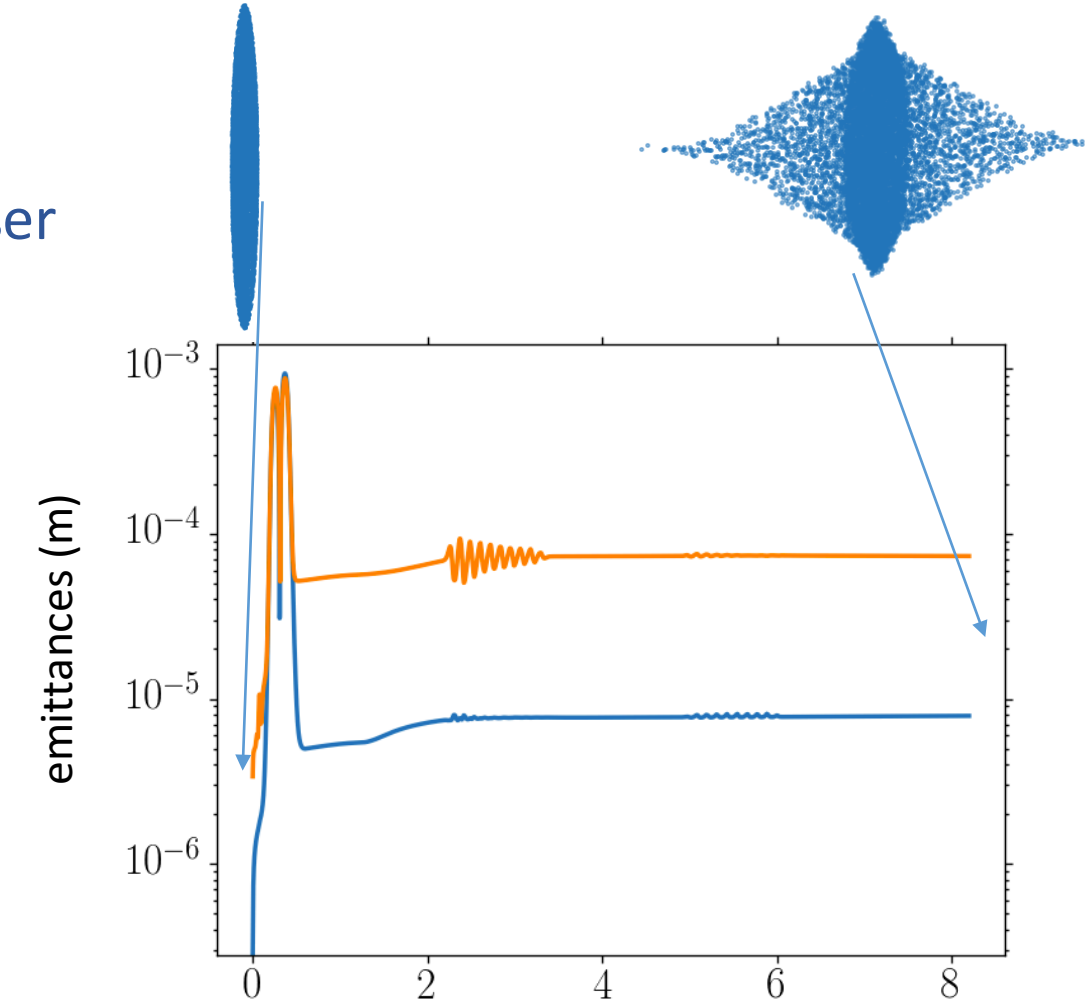
Flat-to-round beam transformation

- Reverse of flat beam transform:
  - Illuminate photocathode with ribbon laser
  - Transform into a magnetized beam
- Preliminary simulations (IMPACT-T)



Y. Derbenev, University of Michigan
report UM-HE-98-04 (1998)

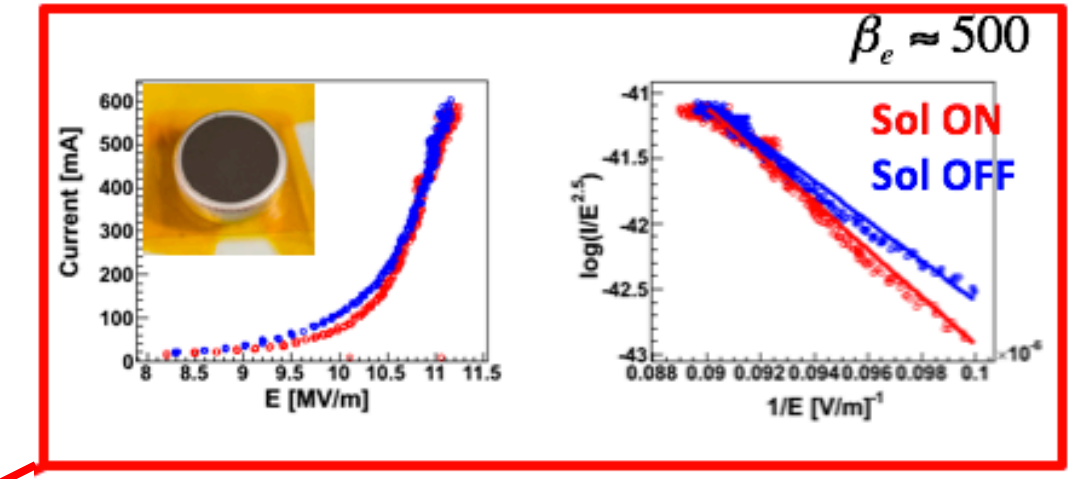
- At FAST/IOTA produced magnetized beam could be injected in IOTA (R. Li)

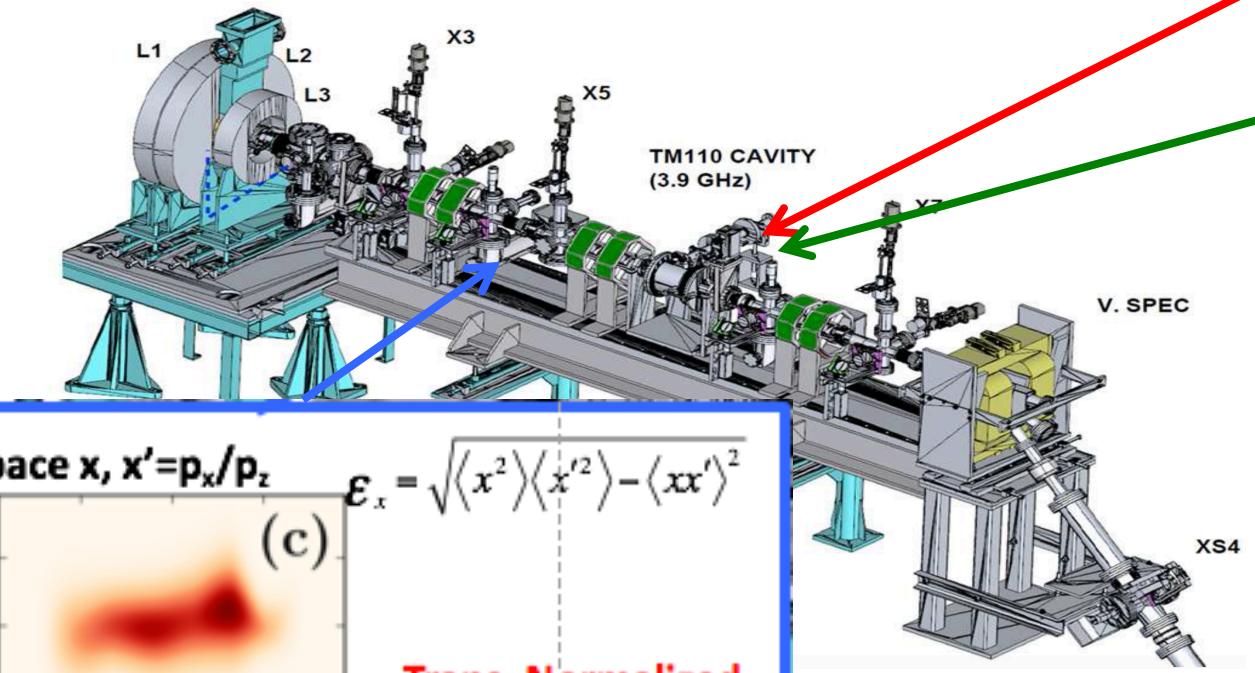


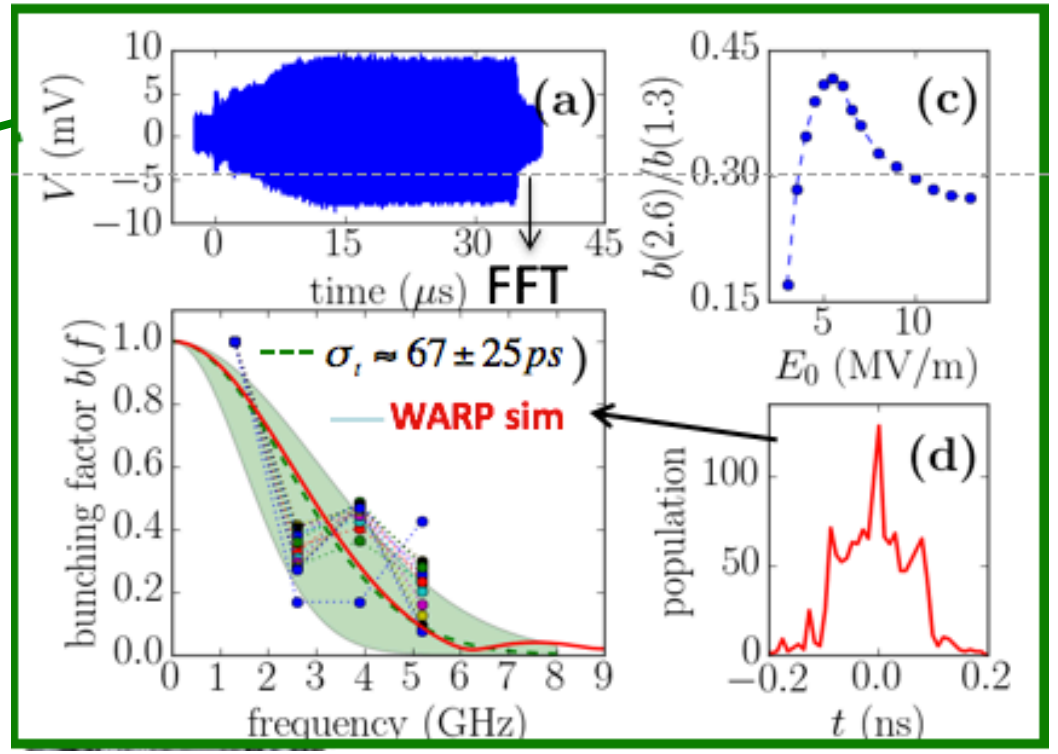
radiabeam TECHNOLOGIES

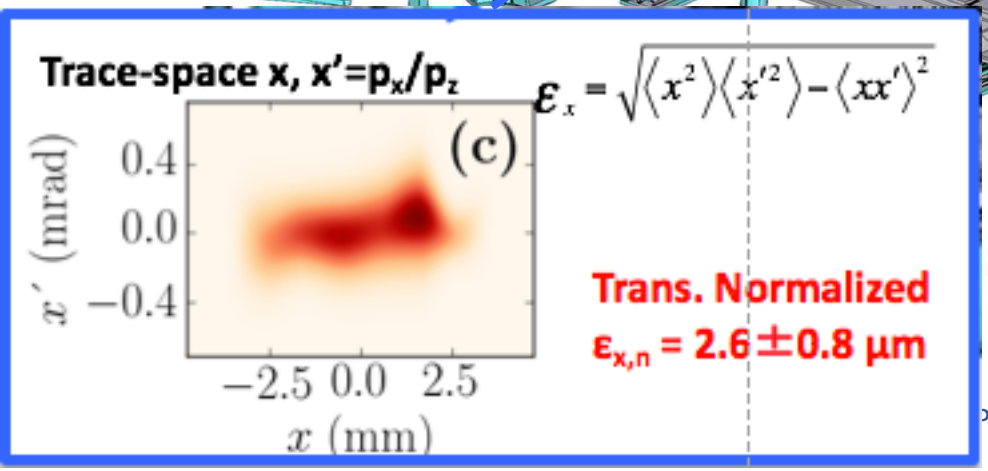
High-current sources

- use field emission by placing cathode in an RF gun (f=1.3 GHz)
- different cathodes tested (here CNT)



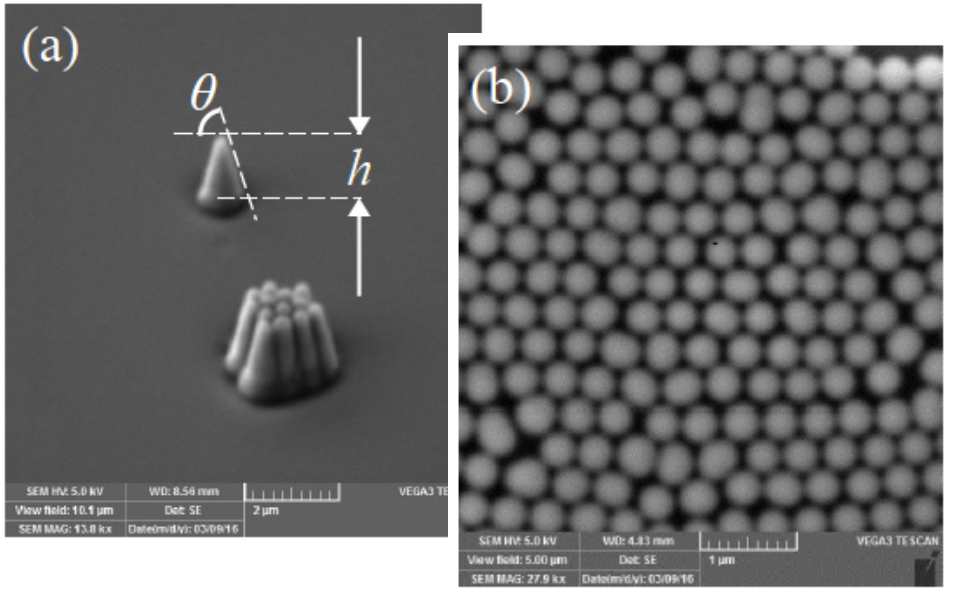






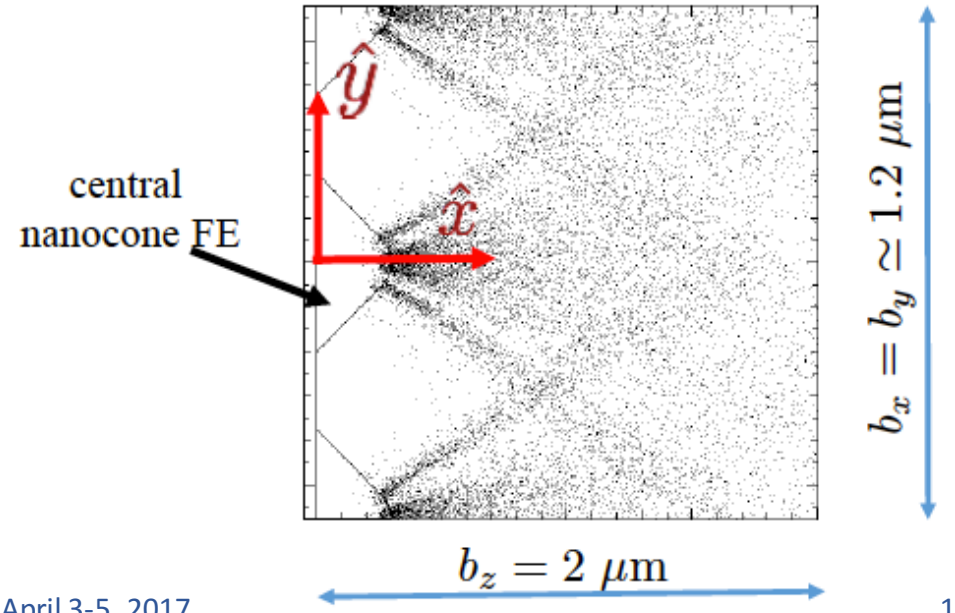
D. Mihalcea et al., APL 107, 033502 (2015)

High-current sources (cnt'd)



- Main issue is proper bunching. Currently working with Fermilab on a 1+1/2 cell gated SCRF gun operating at 650 MHz with gate at 1.3 GHz.
- Field emission cathode lifetime and contamination is also an open issue
  - activity at NIU to test potential cathode in a DC gap over long period of time
  - Simulation of field emission (WARP)

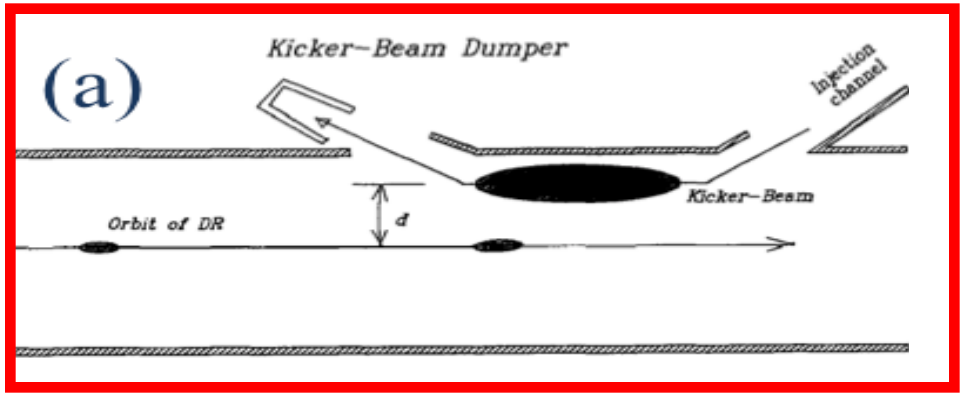
[A. Lueangaramwong et al.,
AIP Conf.Proc. 1812 (2017) no.1, 080009)]

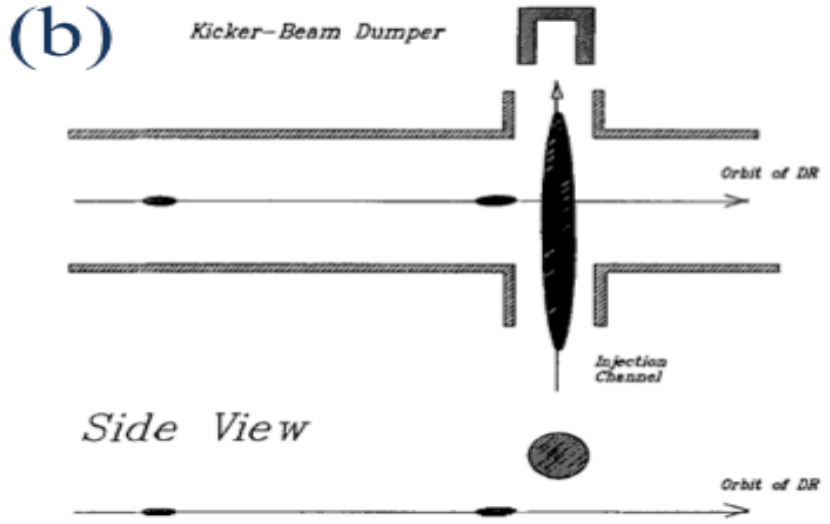


[V. Shiltsev, NIM AA, vol. 374, 137 (1996)]

Interests in the Beam-Beam kicker

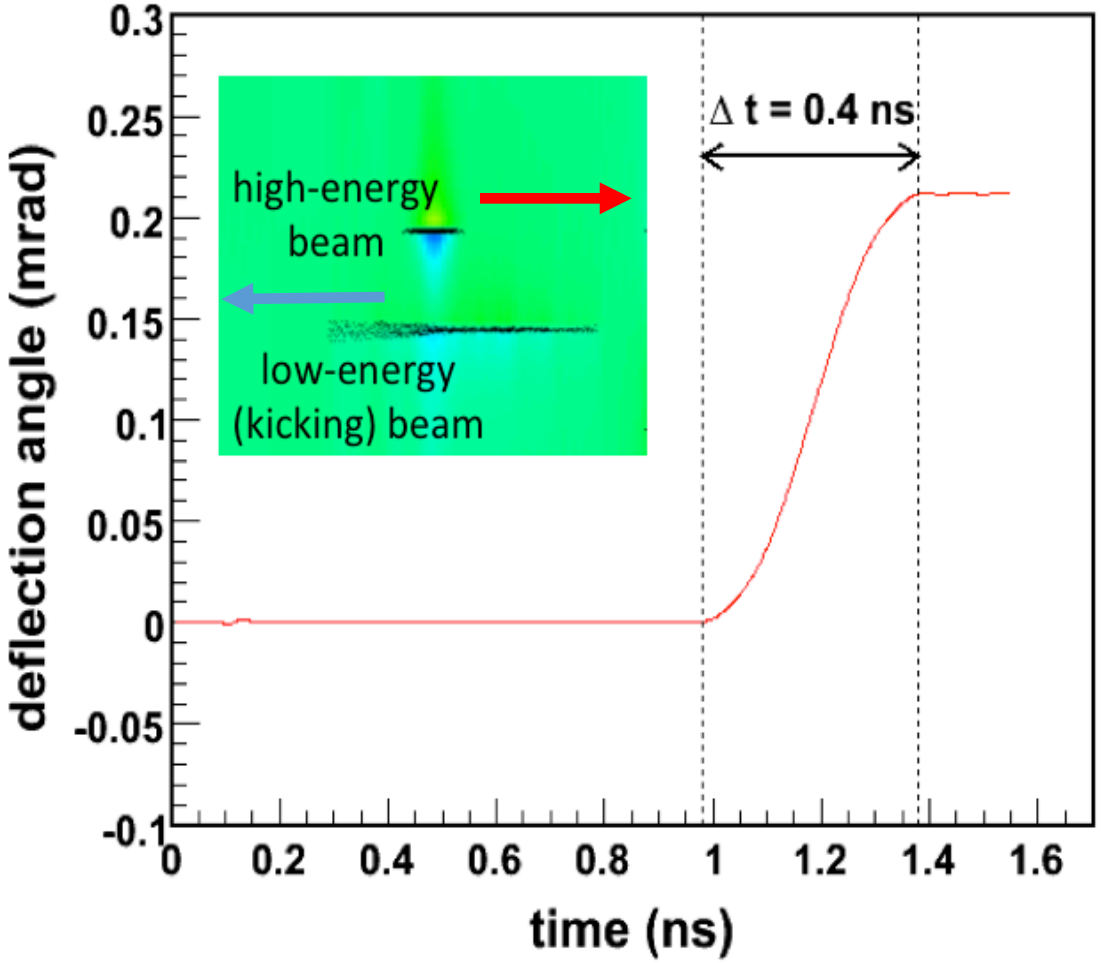
- Simulations:
  - Beam dynamics: degradation of the cooling e- beam, optimization of kicker e-beam parameters
- Experiments:
  - At AWA using the the two-injector configuration currently used for two-beam acceleration in DWFA





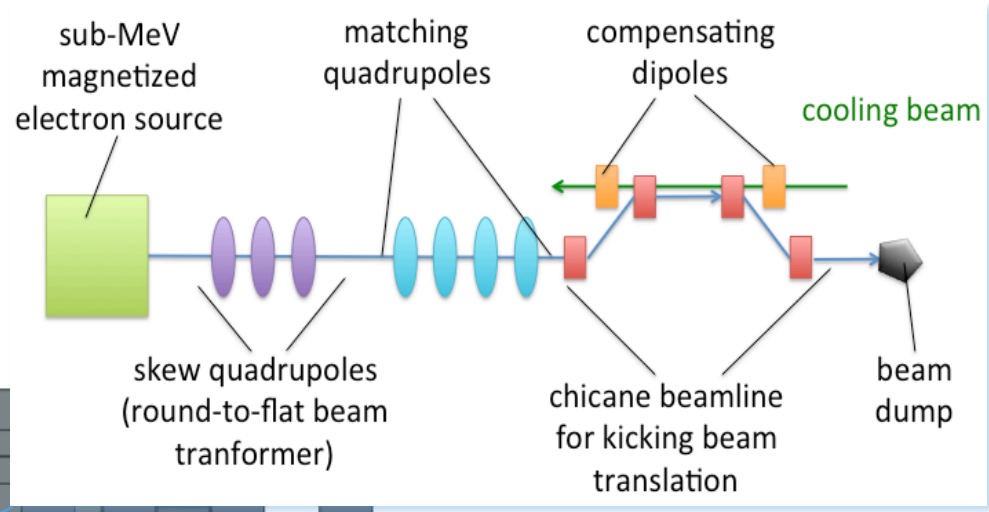
Beam-beam kicker design

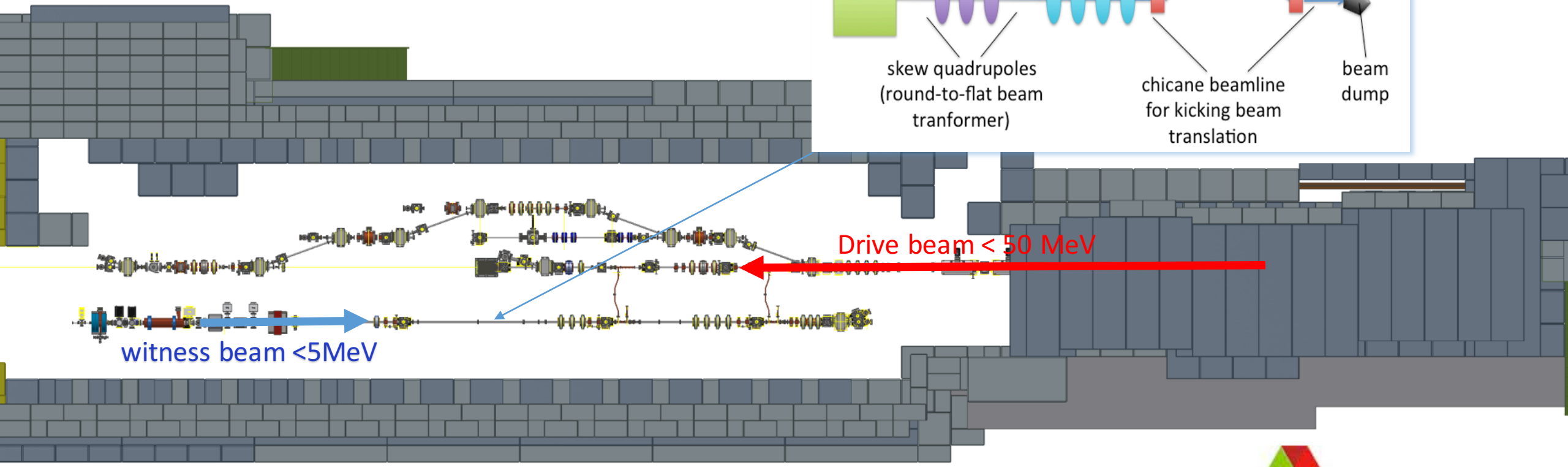
- Preliminary simulations using WARP
  - 1 MeV kicking beam to kick a 50-MeV cooling beam
  - 0.4-ns rise time
- Cooling beam possibly flat so that kicking beam would also need to be flat (+*t*-shaping?)
- Design/test of kicking e-beam could leverage on e-cooling beam electron source



Beam-beam kicker experiment (proposed)

- use the witness beam to kick the drive beam





Summary

- We are interested in collaborating on JLEIC with primary focus on magnetized-beam formation and beam-beam kicker
- So far our work is exploratory and tied to other projects in progress
- Several facilities available at Argonne and Fermilab with parameters relevant to the JLEIC e- cooler could be ideal testbeds:
  - **FAST linac:** magnetized beam, longitudinal manipulation of magnetized beam, round-to-flat and flat-to-round beam transformation
  - **AWA:** two beam setup readily available could support test of beam-beam kicker, work on magnetized beam has also been carried out there, also emittance exchanger used for temporal shaping.
  - **IOTA ring:** recirculation of magnetized beam produced in the FAST linac (suggested by R. Li)

Acknowledgements

- NIU students: C. Buzard, A. Halavanau, A. Lueangaramwong, O. Mohsen
- NIU collaboators: V. Korampally, D. Mihalcea
- Argonne National Lab. AWA team: J. Power, W. Gai, M. Conde
- The material presented has benefited from informal collaborations with
  - Radiasoft: D. Bruhwiler & N. Cook
  - Radiabeam: L. Faillace, A. Murokh
  - EuclidLab: C. Jing, V. Jabotinsky
- The work relies heavily on simulation tools developed at Berkeley (WARP and IMPACT-T/Z).