EIC Accelerator R&D Strategy and Programs

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R&D program is aimed at:

- Confirming design choices
- Developing required technology
- Experimental confirmation of new concepts

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Essential EIC R&D program

Approach:

1) Proof of principle for large improvements over present state of the art – needed for technical plausibility by next LRP:
   - Polarized electron source current (50 mA eRHIC vs. 1 mA at best present sources)
   - ERL operation at high energies and ≥ 50 mA @ eRHIC
   - Hadron beam β* in collider (5 mm @ JLab vs. ~25 cm at existing hadron colliders)
   - Detector operation at 500 MHz @ Jlab
2) Proof of principle of high-energy hadron beam cooling techniques (e.g., Coherent electron Cooling – CeC) to improve luminosity from initial design
3) Technology developments to reduce costs, e.g., in SRF cavity fabrication, compact magnets, …

Joint EIC R&D plan over ~ 5 years (FY08$)

Common R&D activities for eRHIC and ELIC

- Beam-beam simulation for EIC (JLab and BNL)* [6 FTE-yrs; Total: $1.2M]
- Crab cavities (JLab)* [8 FTE-yrs; M&S: $1.2M Total: $2.8M]
- Polarized 3He production and acceleration (BNL) [6 FTE-yrs; M&S: $1.0M Total: $2.2M]
- Coherent Electron Cooling (BNL) [20 FTE-yrs; M&S: $5.0M Total: $9.0M]

R&D activities specific to eRHIC

- High current polarized electron source (MIT)* [8 FTE-yrs; M&S: $2.0M Total: $3.6M]
- Energy recovery technology for high energy and high current beams (BNL) [10 FTE-yrs; M&S: $3.0M Total: $5.0M]
- Development of compact loop magnets (BNL)* [4 FTE-yrs; M&S: $0.5M Total: $1.3M]
- Development of eRHIC-type SRF cavity (BNL)* [10 FTE-yrs; M&S: $2.0M Total: $4.0M]

R&D activities specific to ELIC

- IR design for ELIC (JLab) [9 FTE-yrs; Total: $1.8M]
- Electron cooling studies for ELIC (JLab) [8 FTE-yrs; M&S: $0.5M Total: $2.1M]
- Ion space charge sim. (JLab in collab. with SNS) [2 FTE-yrs; M&S: $0.5M Total: $0.9M]
- Studies traveling focus scheme (JLab) [3 FTE-yrs; Total: $0.6M]
- Spin track studies for ELIC (JLab) [8 FTE-yrs; Total: $1.6M]
- Ion complex R&D (JLab/ANL/ODU) [16 FTE-yrs; M&S: $4.0M Total: $7.2M]

Breakdown between Laboratories

- BNL – $22.1M JLab/ANL/ODU – $17.6M MIT – $3.6M Total: $43.3M

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* partially funded from other sources

Common ELIC and eRHIC R&D Activities

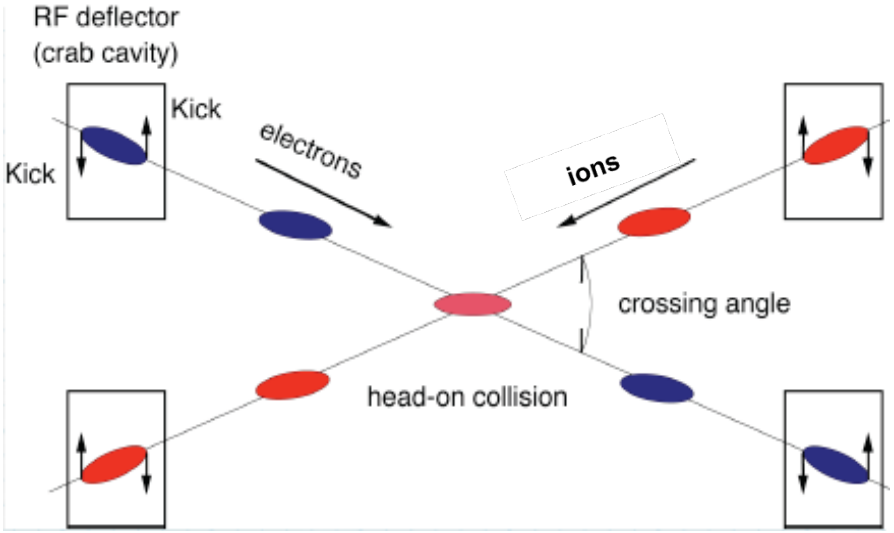
① Develop extensions to existing beam-beam simulations code for electron-ion colliders including all of the special features

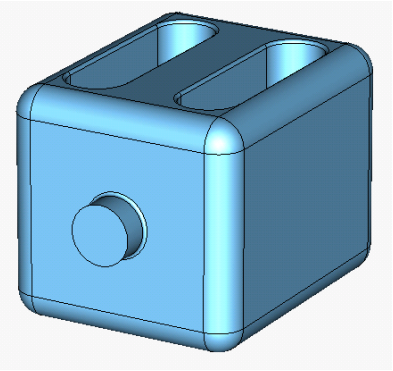
- Electron-ion beam-beam effects, including the kink instability, e-beam disruption and beam emittance growth in a linac-ring and ring-ring colliders
- The interference of multiple interaction points
- BNL and JLab are already working with BeamBeam3D code (funded by SciDAC ComPASS collaboration)

Common ELIC and eRHIC R&D Activities (cont'd)

② Crab cavities to reach high luminosity at non-zero crossing angle (JLab)

- Prototype 500 MHz deflector/crab cavity (Funded by ARRA at JLab)
- Prototype two 1500 MHz crab cavities
- Develop and test phase and amplitude stability scheme(s).

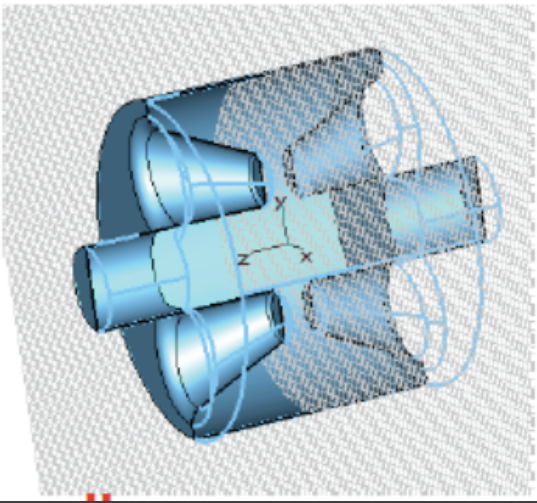




JLab/ODU 500 MHz deflecting/crabbing cavity

Multi-cell TM110 and Loaded Structure of Crabbing Cavity (JLab/Cockcroft/Lancaster)

[R. Palmer 1989; G. Jackson 1990]



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Common ELIC and eRHIC R&D Activities (cont'd)

③ Polarized ^{3}He production and acceleration (BNL)

- Develop of the new Electron Beam Ion Source (EBIS) as spin-preserving ionizer of optically pumped polarized ^{3}He gas.
- Evaluate depolarization due to high anomalous magnetic moment of polarized ^{3}He beams during acceleration in AGS and RHIC.

Common ELIC and eRHIC R&D Activities (cont'd)

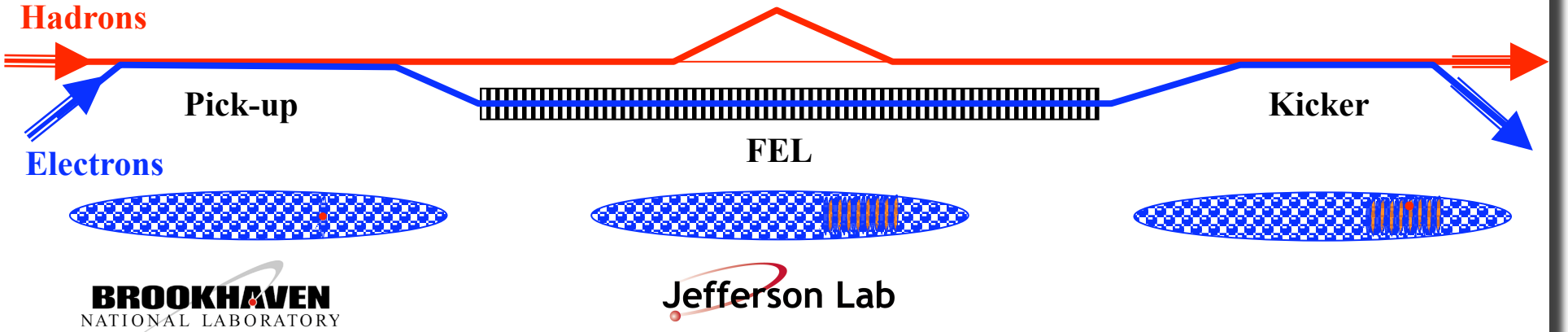
④ Coherent electron cooling (BNL)

- Idea proposed by Y. Derbenev in 1980, novel scheme with full evaluation developed by V. Litvinenko
- Fast cooling of high energy hadron beams
- Made possible by high brightness electron beams and FEL technology
- ~ 20 minutes cooling time for 250 GeV protons → much reduced electron current, higher eRHIC luminosity
- Proof-of-principle demonstration possible with 40 GeV/n Au beam in RHIC.

Pick-up: electrostatic imprint of hadron charge distribution onto co-moving electron beam

Amplifier: Free Electron Laser (FEL) with gain of 100 -1000 amplifies density variations of electron beam, energy dependent delay of hadron beam

Kicker: electron beam corrects energy error of co-moving hadron beam through electrostatic interaction



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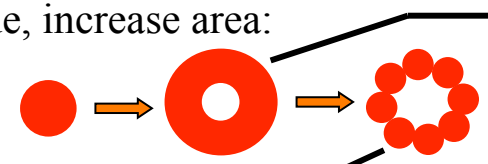
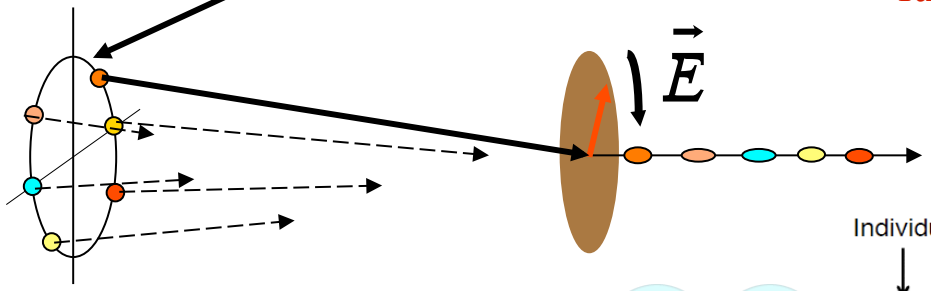
R&D Activities Specific to eRHIC

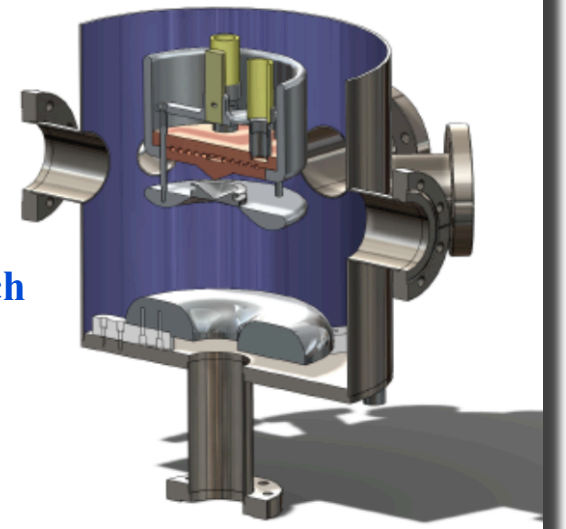
① High current polarized electron source (MIT, BNL)

To relax limitation from ion bombardment damage of photocathode, increase area:

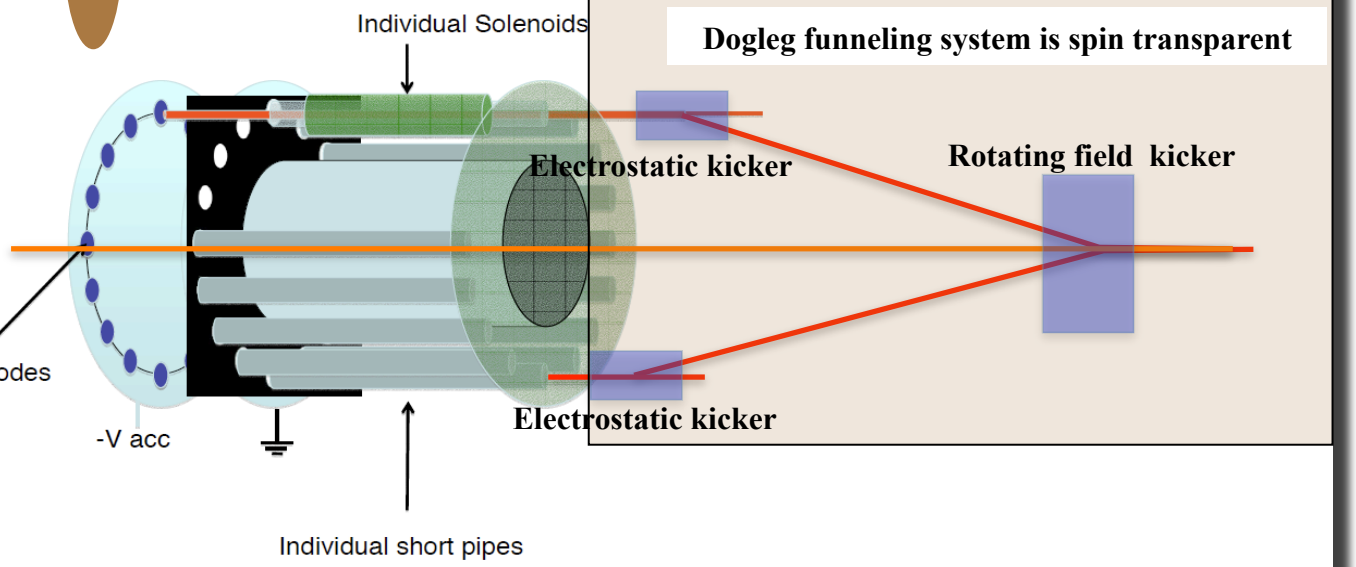




Large annular photocathode under test by E. Tsentalovich @ MIT/Bates funded by DOE



"Gatling gun" approach, using rotating RF field to recombine successive pulses from 24 2-mA guns under design by I. Ben-Zvi @ BNL – 2-gun test funded by BNL LDRD



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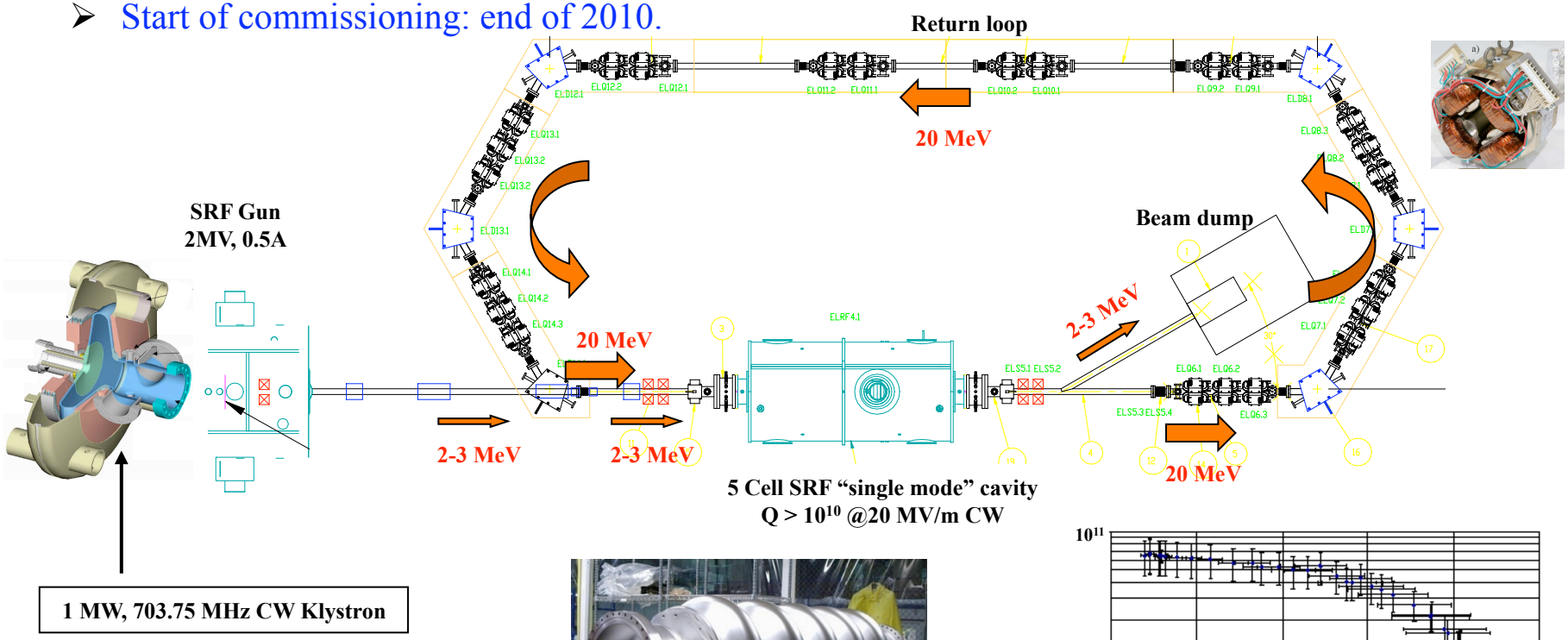
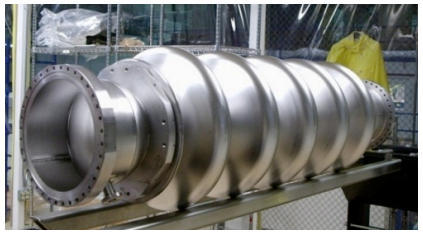
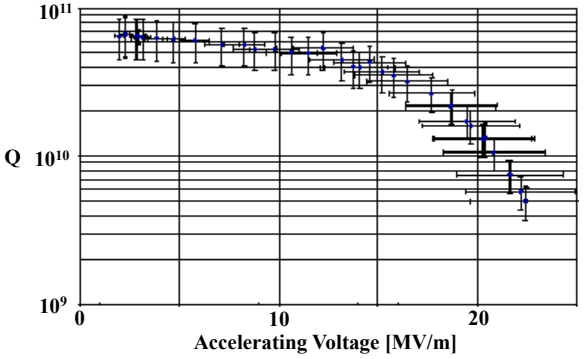
R&D Activities Specific to eRHIC (cont'd)

② Energy recovery technology for high energy and high current beams

- Test of high current (0.5 A), high brightness ERL operation
- Test for 10 – 20 GeV high intensity ERL for eRHIC
- Test of high current beam stability issues, highly flexible return loop lattice
- Allows for addition of a 2nd recirculation loop
- Start of commissioning: end of 2010.







Funded by DOE, Navy, BNL

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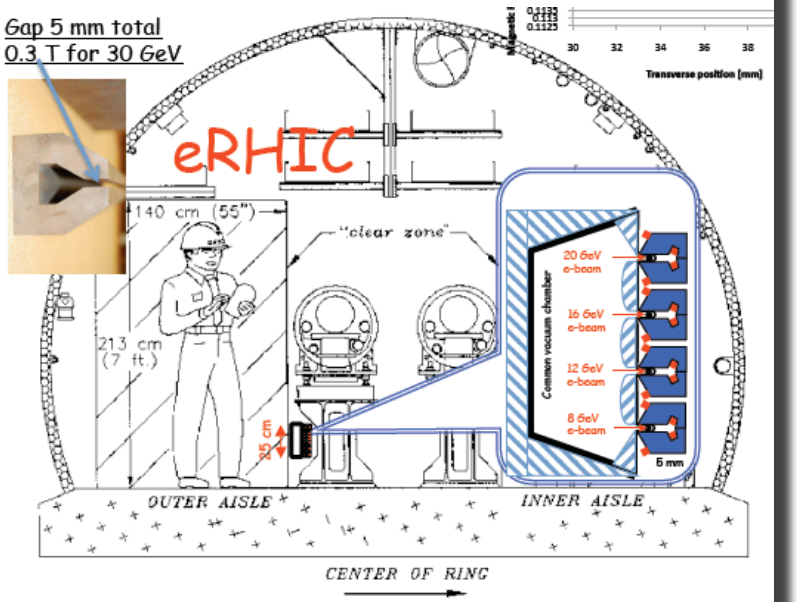
R&D Activities Specific to eRHIC (cont'd)

③ Compact recirculation loop magnets

- Design, build and test prototypes of small gap magnets and there vacuum chamber.

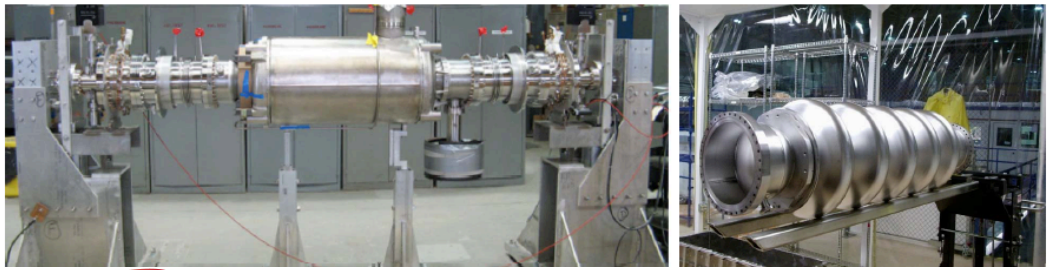
Compact (5 mm gap) dipoles, to allow multiple vertical passes within single vacuum enclosure around RHIC tunnel, under development via BNL LDRD funds.



④ Development of SRF cavity for eRHIC

- Issue: Develop SRF cavities for the main ERL of eRHIC

Funds from DOE, BNL, DOE HEP ARRA



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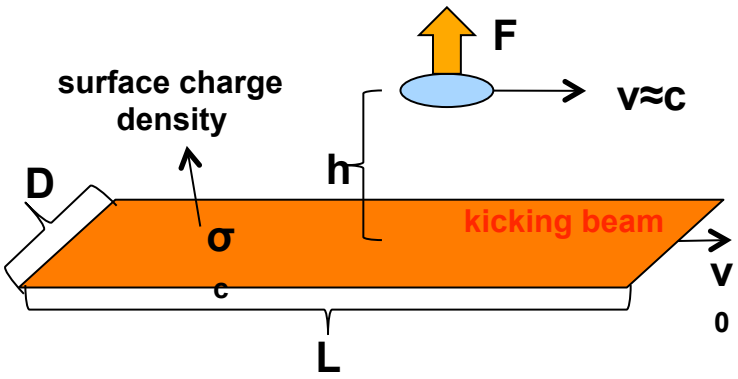
R&D Activities specific to ELIC

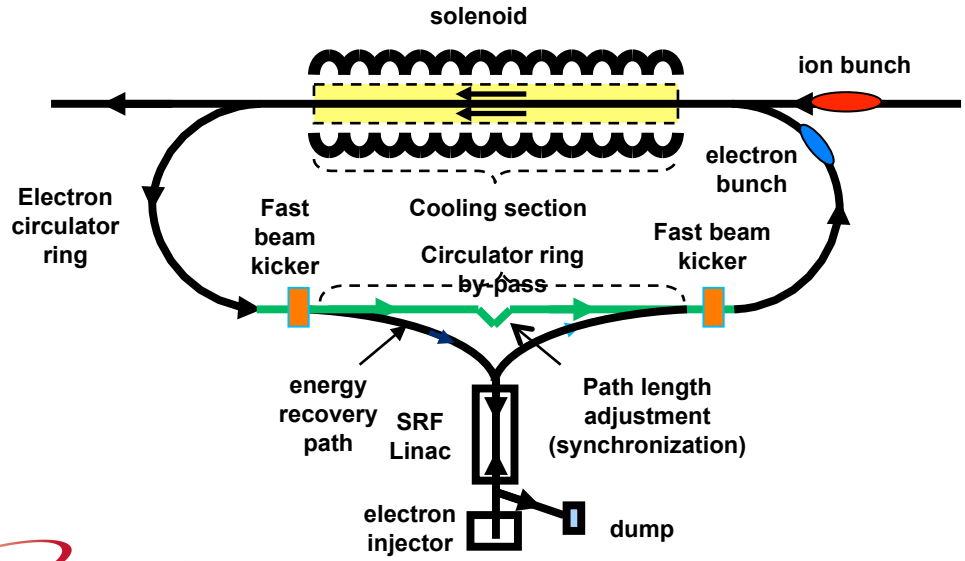
① IR Design

- IR region layout for both rings including detector
- Develop chromatic correction algorithm
- Demonstrate adequate dynamic aperture in both rings
- Evaluate alternate crossing ideas

② Electron cooling

- Simulate electron cooling processes (VORPAL, BETACOOL)
- Study beam dynamics in circulator ring including space charge stability of up to 3A CW electron beam
- Development of the fast kicker





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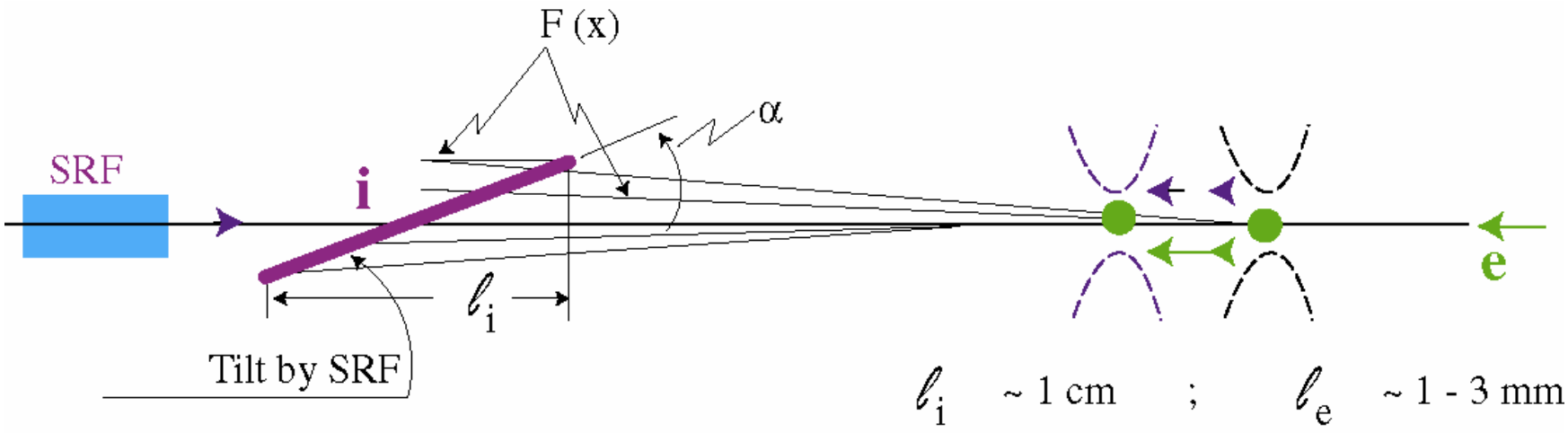
R&D Activities specific to ELIC (cont'd)

③ Ion Space charge simulations (in collaboration with SNS)

- Explore "painting" technique for stacking via simulations
- Experimental investigations in SNS

④ Traveling Focus Study

- Feasibility study
- Develop experimental proof-of-principle program

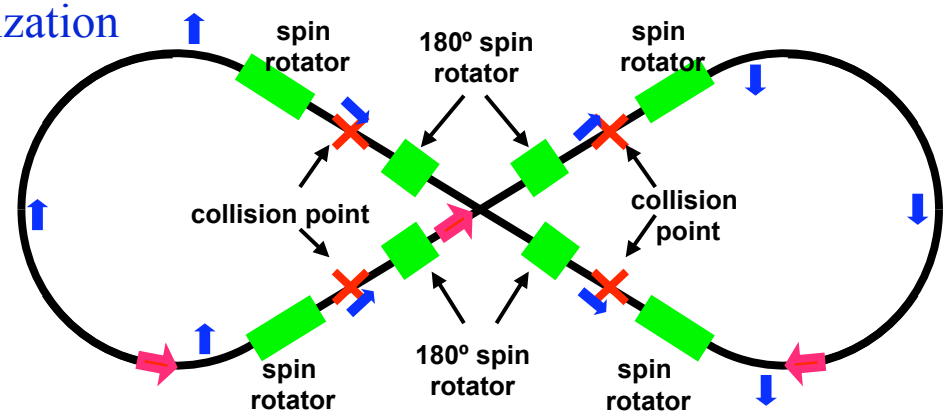


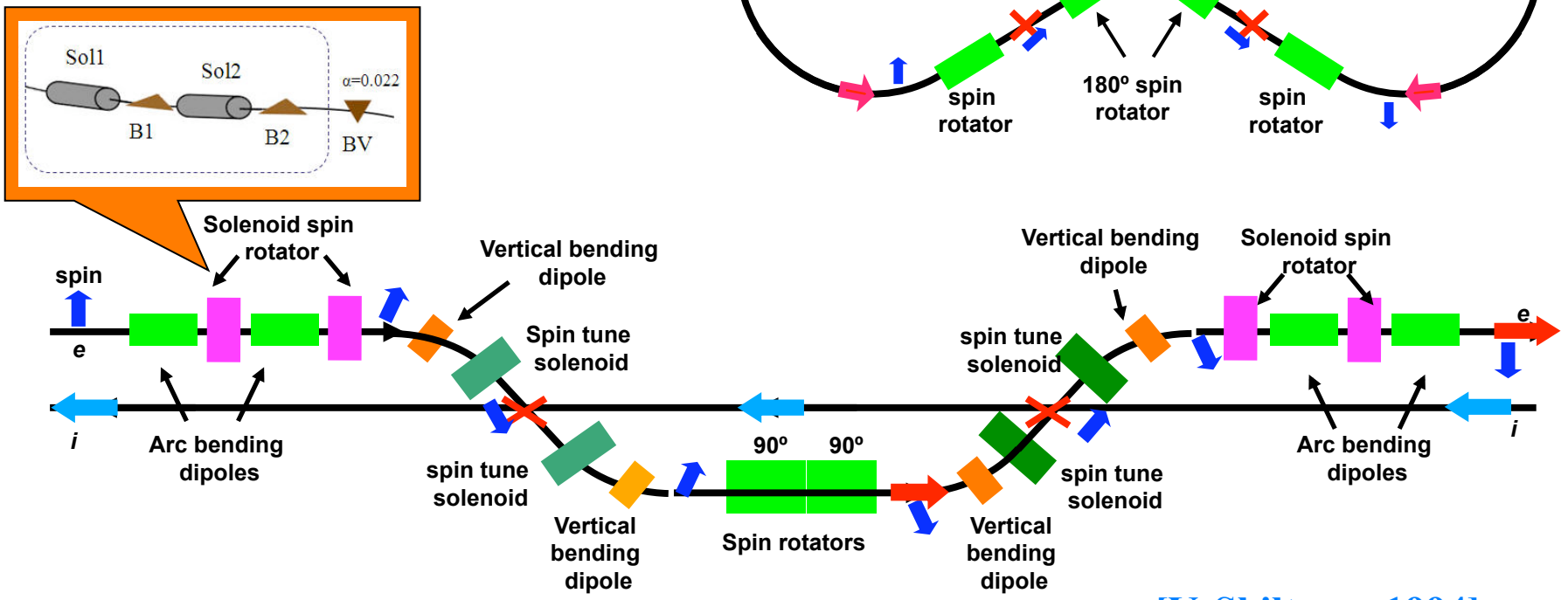
[R. Brinkmann, M. Dolhus 1995; Y. Derbenev 2002]

R&D Activities specific to ELIC (cont'd)

⑤ Spin Tracking Studies for ELIC

- Full electron and ion spin tracking
- Beam-beam effect on spin depolarization





[V. Shiltsev ~1994]

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R&D Activities specific to ELIC (cont'd)

⑥ Technology for high intensity, high brightness ion complex (ODU/ JLab/ANL)

- Beam line and lattice design
- Ion sources
- RFQ
- Linac (SRF cavity development, rf control)

Summary

A joint Accelerator R&D plan has been developed in anticipation of NSAC LRP recommended EIC R&D funding.

The projected total cost is about $45M (FY08$) and extends for about 5 years

Work on several items has started using other funding sources.