Electron Cooling of the Relativistic Heavy Ion Collider: Overview

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Collider-Accelerator Department's Machine Advisory Committee

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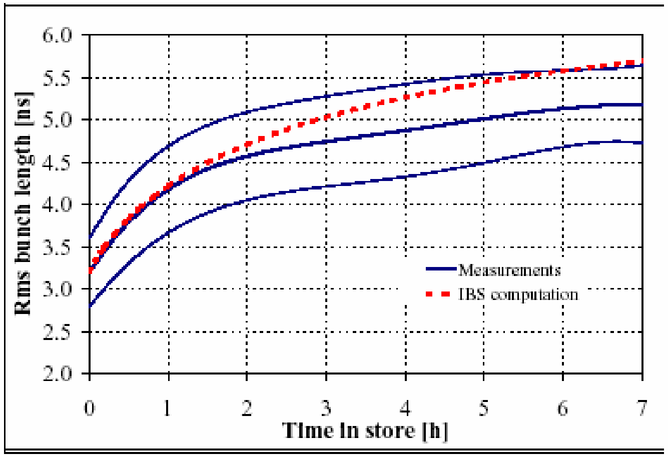
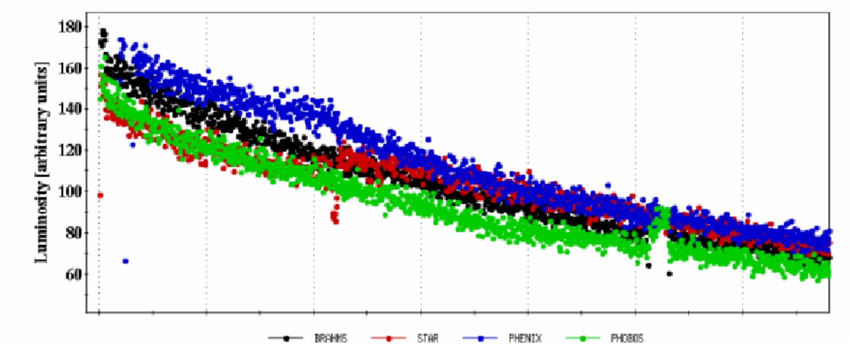
Motivation

- The motivation for electron cooling of RHIC is to increase luminosity by reducing emittance and overcoming IBS.
  - Increase the integrated luminosity for gold on gold collisions by an order of magnitude, also higher P-P luminosity.
  - Increase the luminosity of protons and ions on electrons and shorten ion bunches
- Both RHIC II and eRHIC are on the DOE's 20 years facilities plan.





RHIC luminosity decay (3.5 hours)

What is special about cooling RHIC

The cooling takes place in the co-moving frame, where the ions and electrons experience only their relative motion.

RHIC ion are ~100 times more energetic than a typical cooler ring. Relativistic factors slow the cooling by at least factor of γ^2. So, first and foremost, we must provide a factor of γ^2 more cooling power than typical.

Other points: Cooling of a bunched beam, cooling of a collider, recombination and disintegration, use of a high-temperature electron beam. Transport of a magnetized (angular momentum dominated) beam without a continuous solenoid.

We cannot use conventional accelerator techniques. We require a high-energy (54 MeV), high-current (0.1 to 0.3 A) electron beam for the cooler, based on an Energy Recovery Linac.

R&D issues

- High current, energetic, magnetized, cold electron beam. Not done before
  - Photoinjector (inc. photocathode, laser, etc.)
  - ERL, at x100 the current of current JLAB ERL
  - Beam dynamics study (magnetized beam AND space-charge AND discontinuous solenoid)
- Understanding the cooling physics in a new regime, must reduce uncertainty
  - bunched beam, recombination, IBS, disintegration
  - electron cooling simulations with some precision
- A very long, super-precise solenoid (30 m long, 1-2 Tesla, 8×10^{-6} error)

Structure of the RHIC Electron Cooling R&D

- Electron cooling R&D
  - Experimental R&D
    - ERL
    - Linac cavity
    - Guns
    - Laser, photocathodes
    - Benchmarking experiments
  - Theory / simulations
    - Beam dynamics
    - Electron cooling
      - Friction, IBS
      - Dynamics

Also: Cost and schedule.
Work in progress.

Electron cooling group.
Reporting to Thomas Roser

Ilan Ben-Zvi, Group Leader.
Vladimir Litvinenko, Deputy Group Leader.
Andrew Burrill, RF gun, photocathode and laser.
Rama Calaga, graduate student, SRF cavity, ERL.
Xiangyun Chang, graduate student, beam dynamics.
Alexei Fedotov, cooling simulations.
Dmitry Kairan, RF gun and ERL.
Joerg Kewisch, beam dynamics and simulations.
David Pate, technician.

- Oversight weekly meeting: Derek Lowenstein, Thomas Roser, Dejan Trbojevic, Michael Harrison, Michael Brennan, Waldo MacKay, Steve Peggs, Jie Wei.

Bold type: Making presentations at this meeting.

C-AD Participants from other groups

Mike Blaskiewicz, stability and RF systems
Yuri Eidelman, electron cooling simulations.
Harald Hahn, Superconducting RF and HOMs.
Ady Hershcovitch, plasma physics and beam dump.
<u>Gary McIntyre</u>, Electron Cooling Project Engineer.
Christoph Montag, accelerator physics.
Anthony Nicoletti, cryogenic engineer.
George Parzen, IBS calculations.
James Rank, mechanical engineer.
<u>Thomas Roser</u>, Head of Accelerator Division.
Joseph Scaduto, facility Engineer.
Alex Zaltsman, high-power RF.

Other Participants

Animesh Jain (BNL Superconducting Magnet Div.), solenoid
Triveni Rao (BNL Instrumentation Div.), photocathode and laser.
Kuo-Chen Wu (BNL Superconducting Magnet Div.), cryogenics.
Vitaly Yakimenko (BNL Physics Dep.), accelerator physics.
Yongxiang Zhao (BNL Physics Dep.), cavity RF, HOMs, control.
GSI/INTAS collaboration: O. Boine-Frankenheim, others.
JLAB: J. Delayen, Ya. Derbenev, P. Kneisel, L. Merminga.
JINR (Dubna), Russia: I. Meshkov, A. Sidorin, A. Smirnov, G. Trubnikov
BINP, Russia: V. Parkhomchuk, A. Skrinsky, many others.
FNAL: A. Burov, S. Nagaitsev.
SLAC: D. Dowell.
Advanced Energy Systems: M. Cole, A. Burger, A. Favale, D. Holmes, A. Todd, J. Rathke, T. Schultheiss.
Tech-X, Colorado: D. Abell, D. Bruhwiler, R. Busby, J. Cary.

Bold type: Making presentations at this meeting.

Electron cooling theory, simulations and benchmarking experiments

- Lead – Alexei Fedotov

Objective: Reduce the extremely large uncertainty in calculating cooling rates, develop new software tools and benchmark them.

Status: Three software tools in various stages of development. Expect solid results in FY05.

Very broad collaboration:

BNL team:
A. Fedotov, I. Ben-Zvi, Yu. Eidelman, J. Kewisch, V. Litvinenko, G. Parzen

JINR (Dubna), Russia: I. Meshkov, A. Sidorin, A. Smirnov, G. Trubnikov

BINP, Russia: V. Parkhomchuk, A. Skrinsky, others.

Tech-X, Colorado: D. Bruhwiler, D. Abell, R. Busby, J. Cary.

FNAL: A. Burov

JLAB: Ya. Derbenev

GSI/INTAS collaboration: O. Boine-Frankenheim, others.

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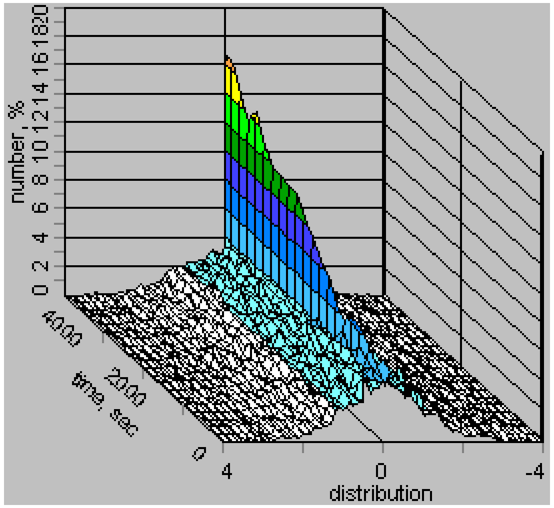
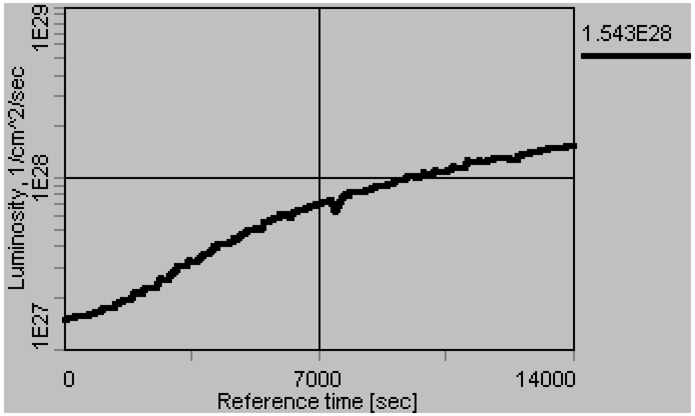
RHIC

Results from Betacool



Beam profile evolution



Luminosity vs. time

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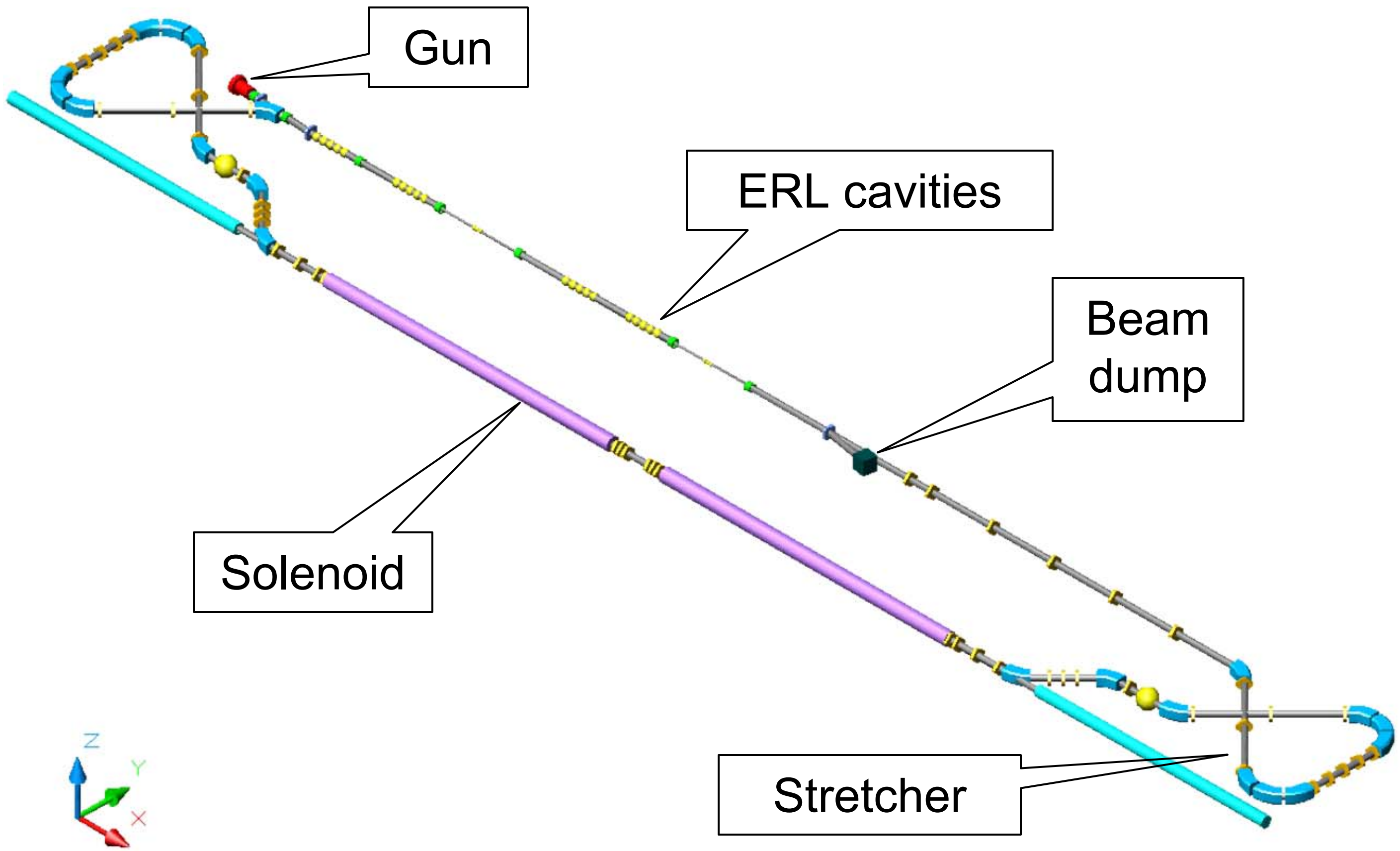
Electron dynamics R&D

- Lead - Joerg Kewisch

The objective is a complete design of the electron accelerator, including start-to-end simulation. Understanding emittance growth under high space-charge forces is important as well transport and matching of magnetized electrons.

Status: Basic simulation tools at hand, initial start-to-end simulation done, new understanding of physics gained. To be completed in FY2006 with a test.

Layout of RHIC electron cooler



Each electron bunch is used just once.

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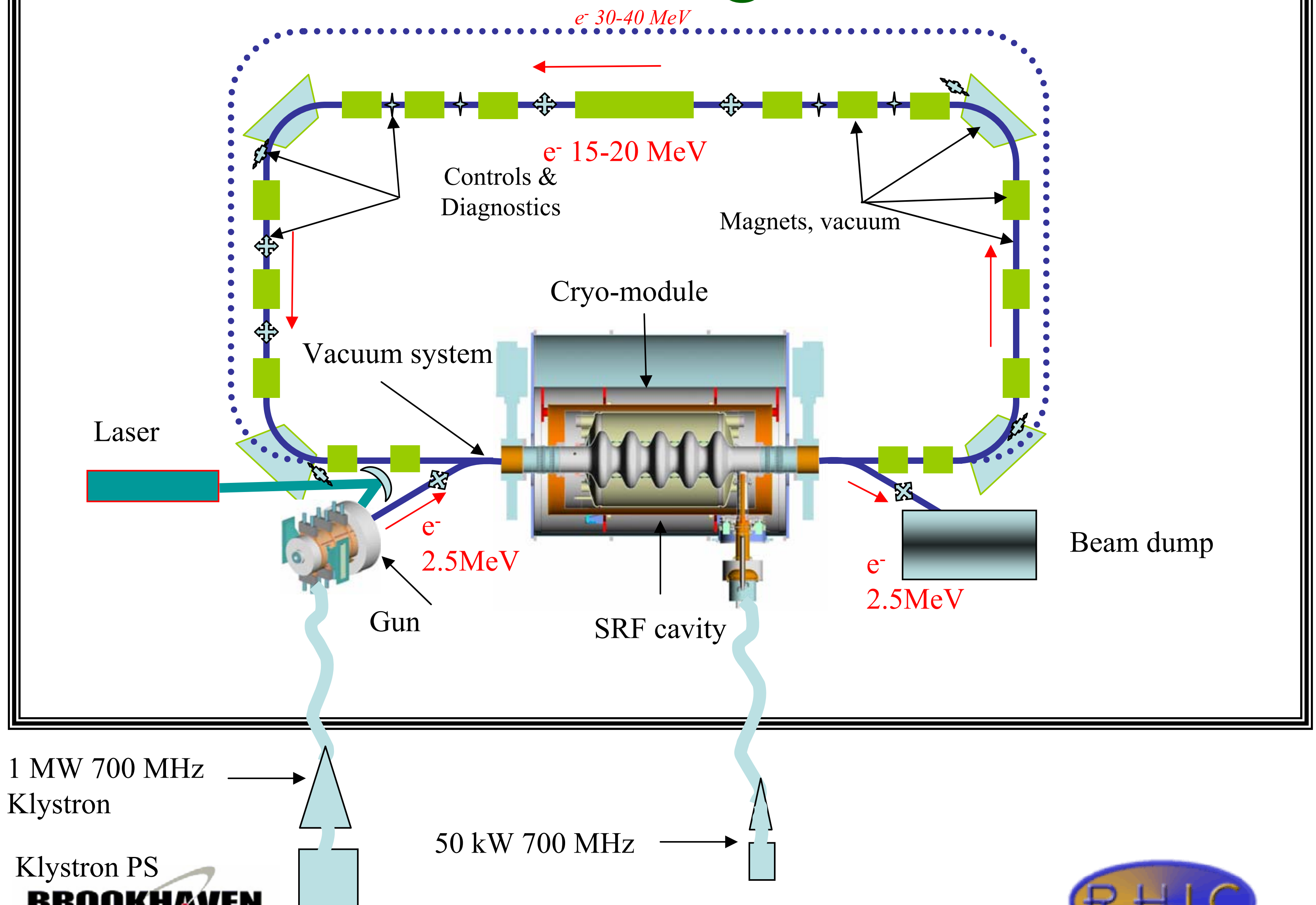
Development of complete ERL

- Lead - Vladimir Litvinenko

The objective is to build an ERL comprising a CW photoinjector, superconducting cavity and beam transport and test it for the RHIC/eRHIC current limits.

Status: Basic beam optics design done for up to 0.5 amperes. Testing system in 2006.

ERL - Bldg. 912



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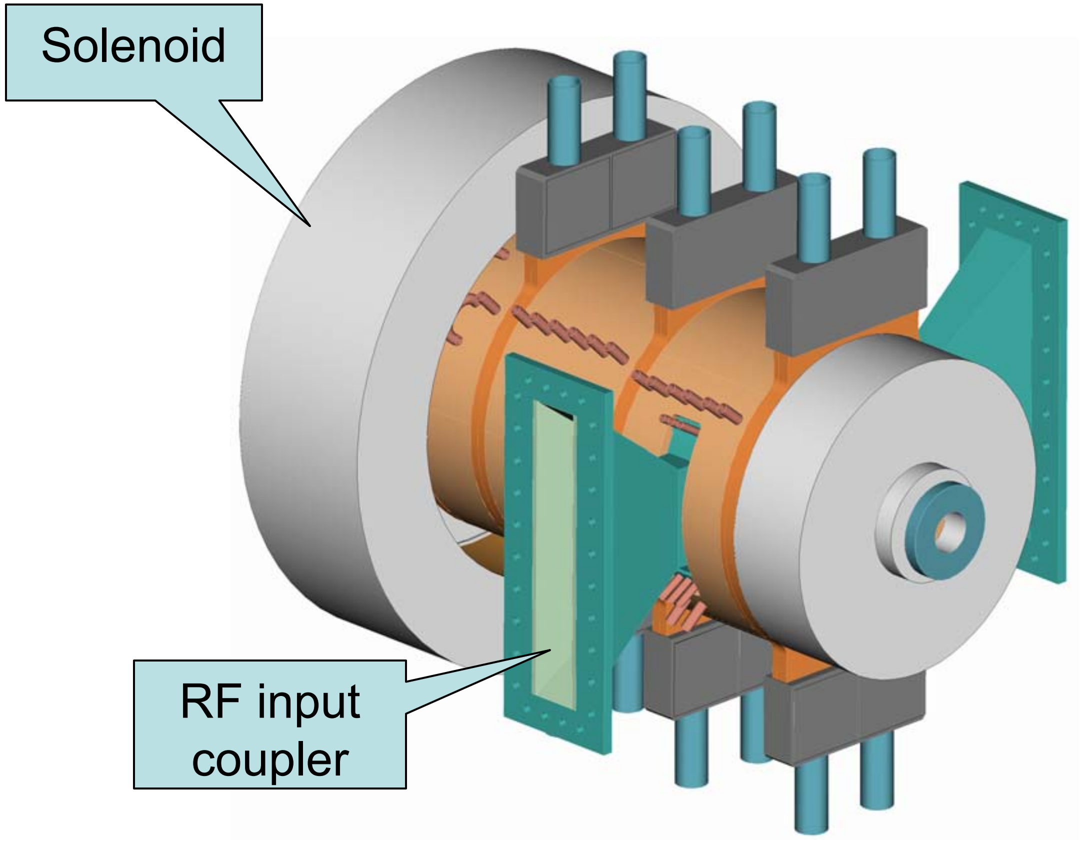
CW - Photoinjector - Glidcop, 703.75 MHz



LANL and Advanced Energy Systems

New 703 MHz
CW Photoinjector
Under construction

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Photocathode and laser

- Lead – Triveni Rao

The objective: Develop a photocathode material that has a high quantum efficiency in the green and long life. Develop suitable laser technology.

Status: UHV deposition chamber operational, CsK_2Sb cathode depositions started. Cathode will be provided for photoinjector in FY05.

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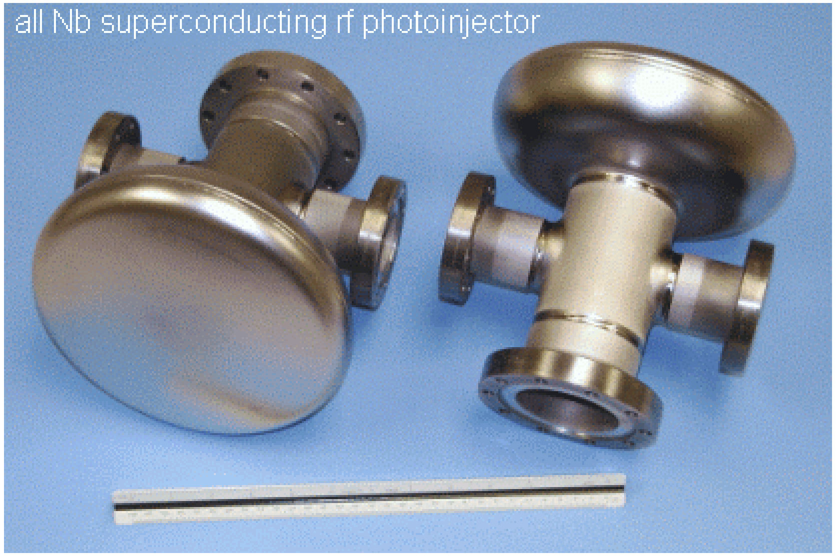
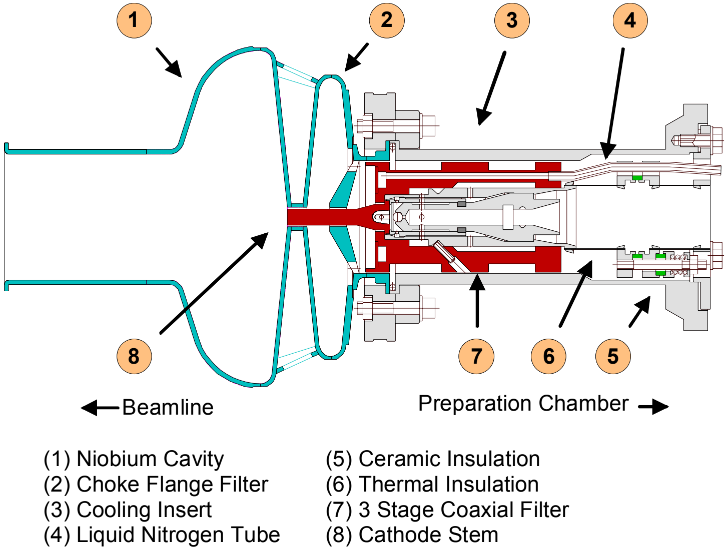
Superconducting gun

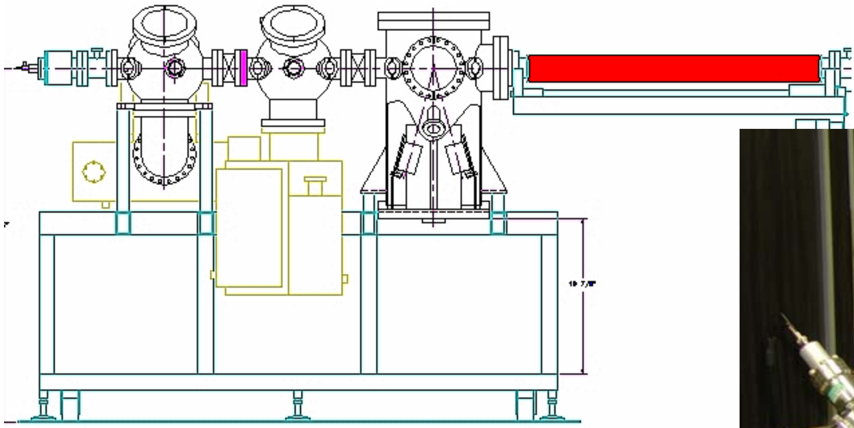


AES – BNL – JLAB gun



Possible direction?
Rossendorf gun with CsK_2Sb

CsK_2Sb Photocathode



UHV photocathode preparation system

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High current ERL SRF cavity

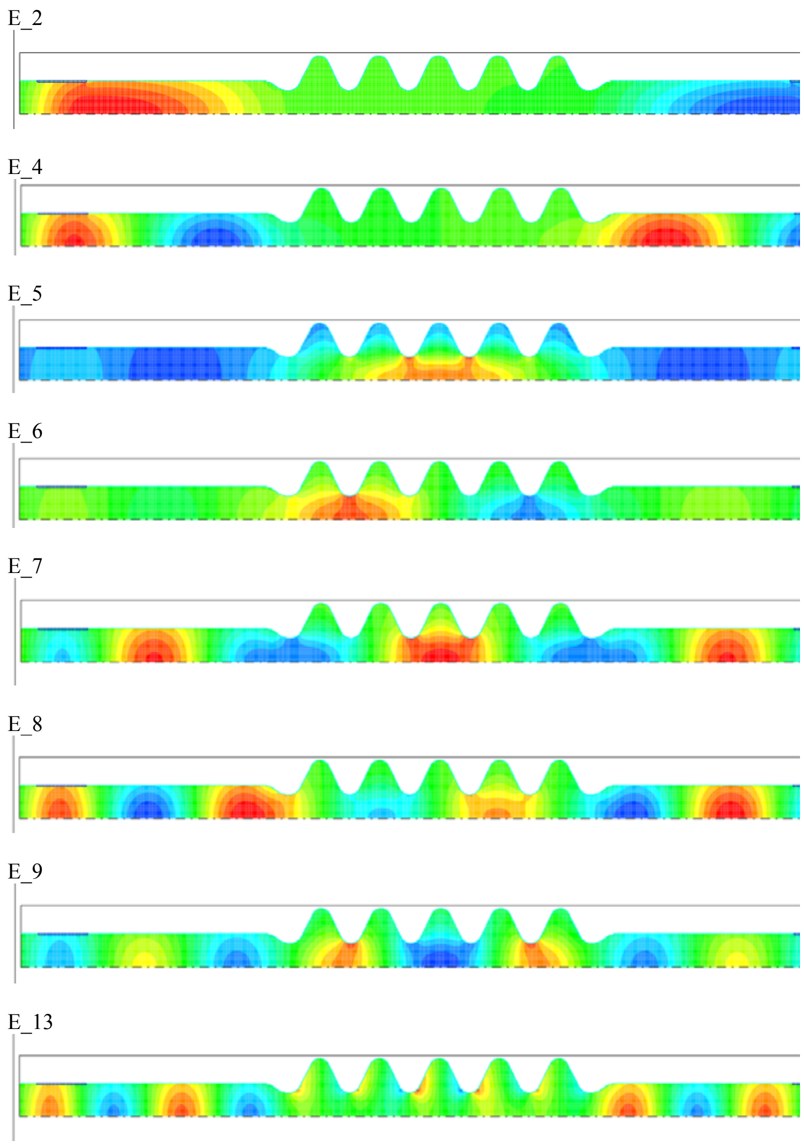
- Lead – Ilan Ben-Zvi

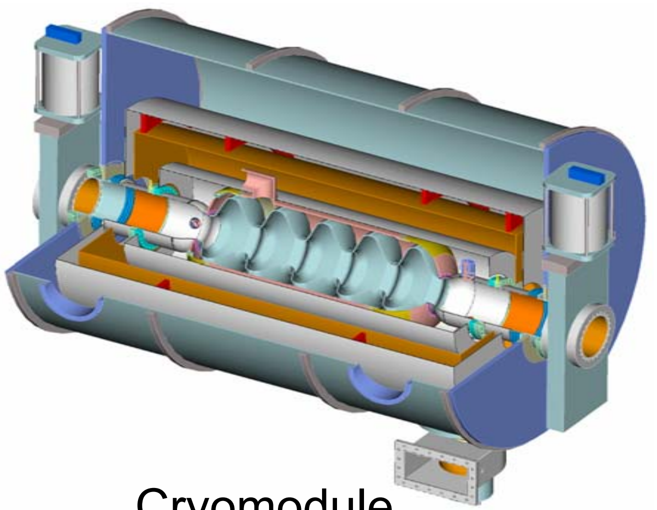
Objective: Develop a cavity for high average current (about 100 times the JLAB ERL), with large-charge bunches (difficult HOM power handling)

Status: Design successfully finished, contract for manufacturing in place. Cold test June 2004, cavity delivered for tests in May 2005.

HOM Calculated By MAFIA.

All HOMs are extremely Well damped.





Cryomodule

Copper cavity parts

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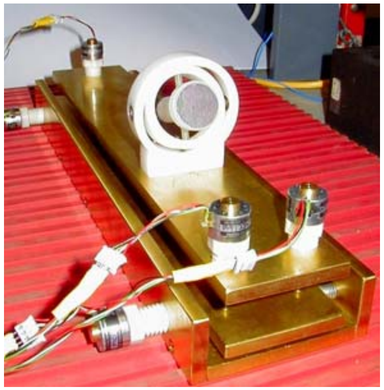
Superconducting solenoid

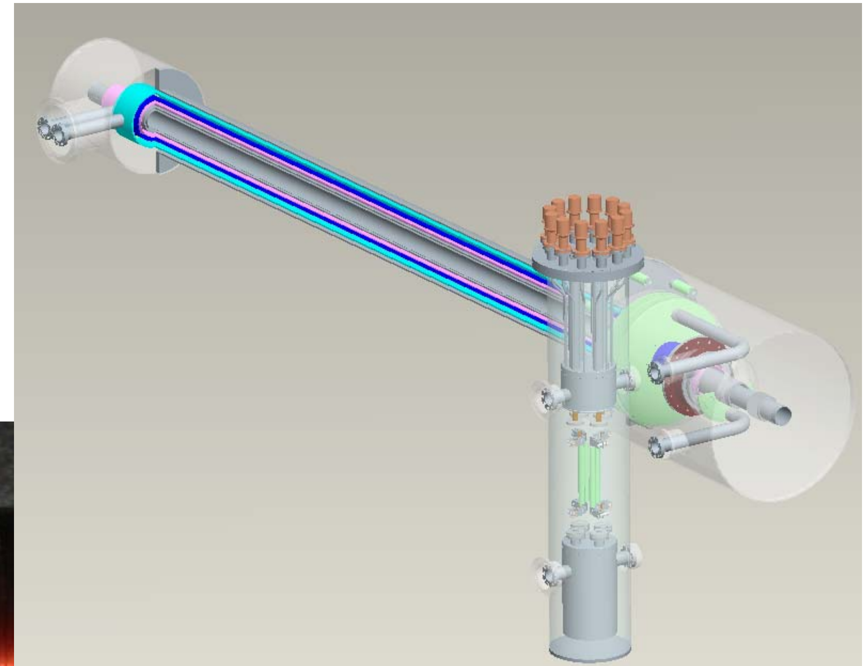
- Lead –Animesh Jain

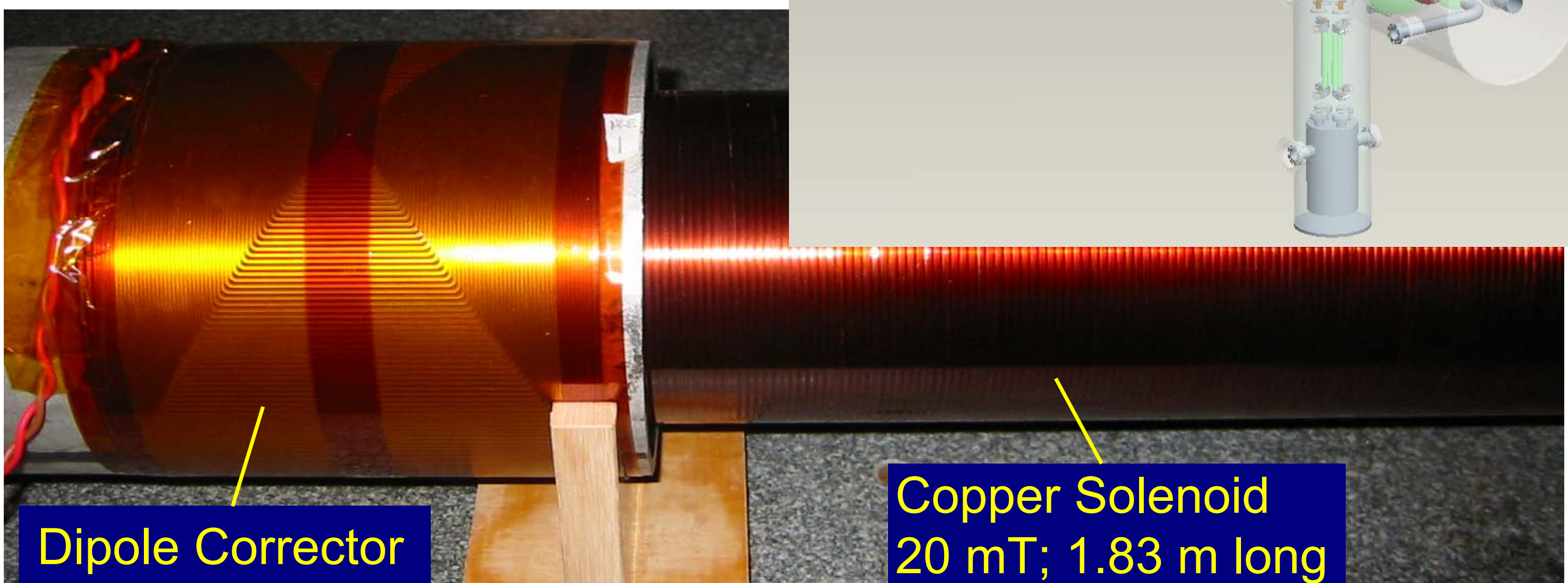
Objective: Develop a prototype superconducting solenoid and its measurement system, demonstrate ability to deliver ultra-high precision in two 13 m long sections, 1 T superconducting solenoid.

Status: Solenoid principles established, Prototype design under way. Correction system under tests.

Conceptual Design of Solenoid







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Conclusions

- High energy electron cooling looks feasible, but requires R&D.
- We emphasize the challenges, but we are confident that cooling RHIC will work well.
- An aggressive and comprehensive R&D program is in place.
- In about three years we expect to resolve all outstanding R&D issues.