# Status of the R&D Towards Electron Cooling of RHIC

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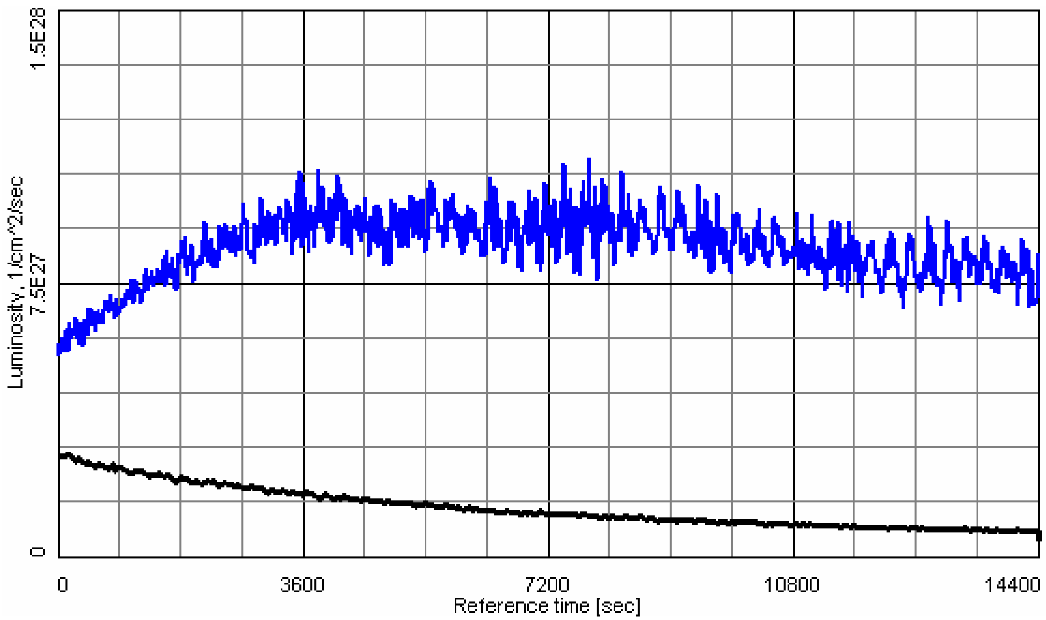
# This is the work of many people and a number of institutions

- Advanced Energy Systems, Medford / Princeton
- Brookhaven National Laboratory, Upton
  - Collider-Accelerator Department
  - Instrumentation Division
  - Superconducting Magnet Division
- Budker Institute of Nuclear Physics, Novosibirsk
- Fermi National Laboratory, Batavia
- Joint Institute of Nuclear Research, Dubna
- Jefferson Laboratory, Newport News
- Oak Ridge National Laboratory, Oak Ridge
- Tech-X Corporation, Boulder

# Why cool RHIC?

- Evolution of RHIC to a QCD laboratory calls for a luminosity increase.
- Most of the luminosity increase will be through electron cooling.
- Electron cooling is also important for eRHIC.
- The energy range is an order of magnitude above the FNAL cooler, the highest energy electron cooler so far.




The luminosity evolution following electron cooling of 100 GeV/A gold beams at RHIC
A. Fedotov,
RHIC Plans Towards Higher Luminosity
Invited talk TUZAKI01

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# What are the R&D issues?

- Understanding the cooling physics in a new regime to reduce uncertainty
  - cooling dynamics simulations with some precision
    - **IBS**, recombination, disintegration
    - benchmarking experiments and computations
    - stability issues
- Developing a high current, energetic, low emittance electron beam
  - SRF Photoinjector (including photocathode, laser, etc.). Expected performance 5 nC, rms normalized emittance 3$\mu$m
  - Energy Recovery Linac, aiming at 0.5 ampere current
    - Preservation of high-charge, low emittance beam
    - Wakes, instabilities, space-charge

# Significant progress on R&D

**25 presentations at PAC07:**

A. Fedotov, RHIC Plans Towards Higher Luminosity, TUZAKI01
D. Bruhwiler et al, Scaling VORPAL Electron Cooling Simulations to Larger Domains on >1,000 Processors THPAS018
G.I. Bell et al, Numerical Algorithms for Modeling Electron Cooling in the Presence of External Fields THPAS017
A. Sobol et al, Quantifying Reduction of the Friction Force due to Magnet Imperfections THPAS024
A. Fedotov et al, High-Energy Electron Cooling Based on Realistic Six-Dimensional Distribution of Electrons THPAS093
A. Fedotov et al, Electron Cooling in the Presence of Undulator Fields THPAS092.
G. Wang et al, Coherent Instability of RHIC Ion Beam due to Electron Cooling THPAS104
D. Kayran et al, Optics of a Two-Pass ERL as an Electron Source for a Non-Magnetized RHIC-II Electron Cooler THPAS096
J. Kewisch et al, Low Emittance Electron Beams for the RHIC Electron Cooler THPMS087
J. Kewisch et al, Emittance Compensation for Magnetized Beams THPMS088,
V. Ranjbar et al, High-Order Modeling of an ERL for Electron Cooling in the RHIC Luminosity Upgrade FRPMS032
E. Pozdeyev et al, Collective Effects in the RHIC-II Electron Cooler THPAS100
E. Pozdeyev et al. Electron Beam Alignment in the RHIC II Cooling Section FRPMS117
E. Pozdeyev et al. Diagnostics of BNL ERL FRPMS116
X. Chang et al, High Average Current Low Emittance Beam Employing CW Normal Conducting Gun WEPMS090
V.L. Litvinenko et al, Status of R&D Energy Recovery Linac at Brookhaven National Laboratory TUPMS076
D. Kayran et al, Merger System Optimization in BNL's High Current R&D ERL THPAS097
V.L. Litvinenko et al, Unique features in magnet designs for R&D Energy Recovery Linac at BNL MOPAS097
A. M. Todd et al, High-Current Accelerator Development for FELs and ERLs
A. Burrill et al, Challenges Encountered during the Processing of the BNL ERL 5 Cell Accelerating Cavity WEPMS088
A. Burrill et al, Multipacting Analysis of a Quarter Wave Choke Joint Proc WEPMS089
X. Chang et al, Recent Progress on the Diamond Amplified Photo-cathode Experiment WEOCC04
D. Dimitrov et al, 3D Simulations of Secondary Electron Generation & Transport in a Diamond THPAS020
Q. Wu et al, Thermal Emittance Measurement Design for Diamond Secondary Emission TUPMS089
H. Hahn et al, Ferrite-lined HOM Absorber for the e-Cool ERL THPAS095

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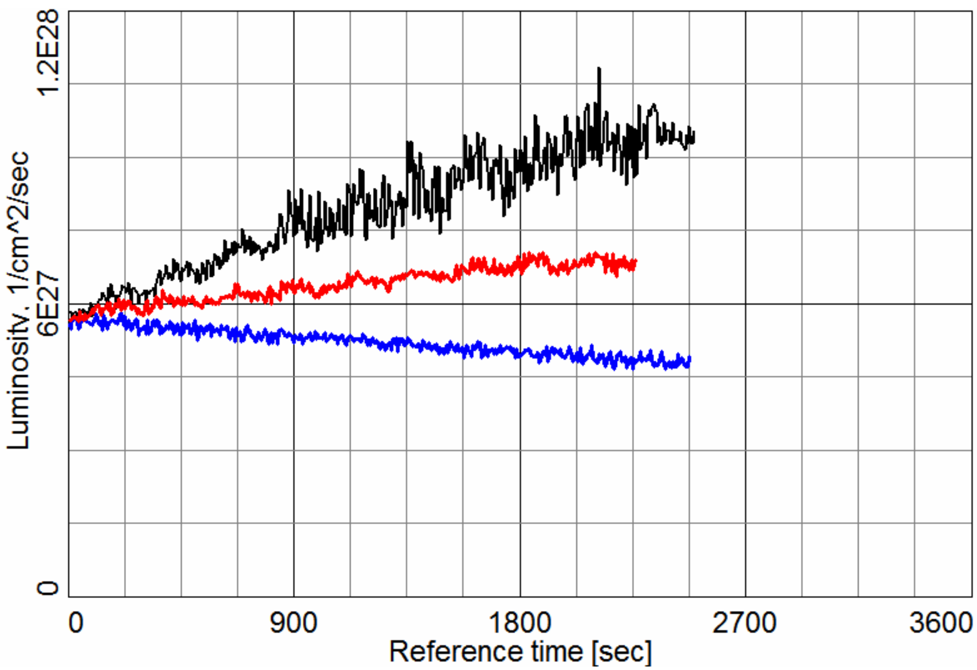
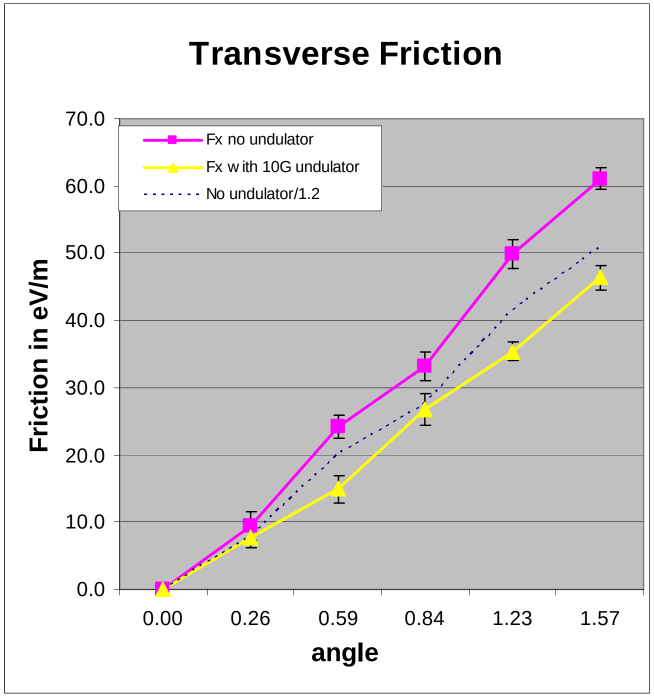
# Where are we now?

- Research towards high-energy electron cooling of RHIC is now in its 6th year
- Feasibility of the luminosity increase of RHIC via electron cooling was demonstrated through
  - numerical simulations of the electron cooling process,
  - Benchmarking experiments, and
  - numerical simulations of the electron beam dynamics of the electron cooler.

# A few examples – cooling simulations




Electron cooling with realistic 6-D electron distributions. Black – using electron distribution at the start of the cooling section. Red (based on the local model) and blue (based on global parameters) using distribution at the end of the cooling section. A. Fedotov et al, High-Energy Electron Cooling Based on Realistic Six-Dimensional Distribution of Electrons. THPAS093

The effect of undulators on the friction force, VORPAL simulation,
Red – without undulator.
Yellow – with a 10 Gauss undulator.
G.I. Bell et al, Numerical Algorithms for Modeling Electron Cooling in the Presence of Ext. Fields THPAS017

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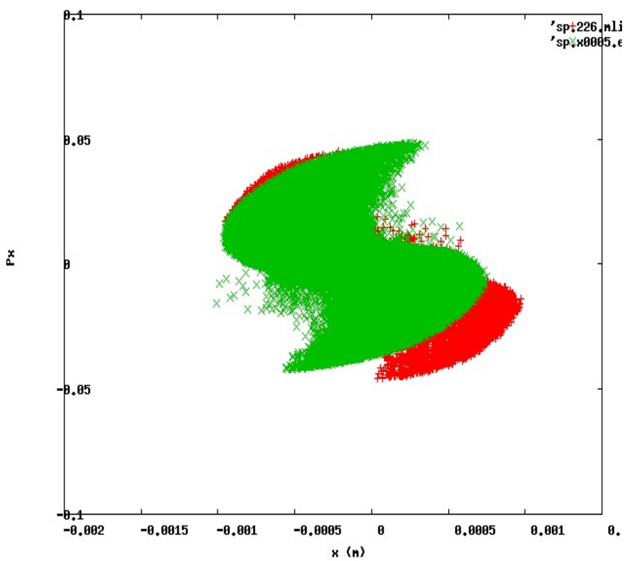
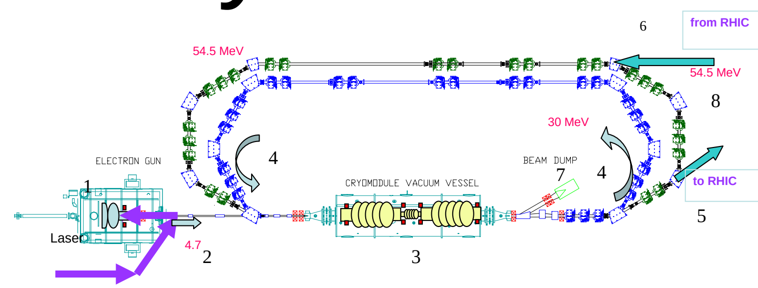
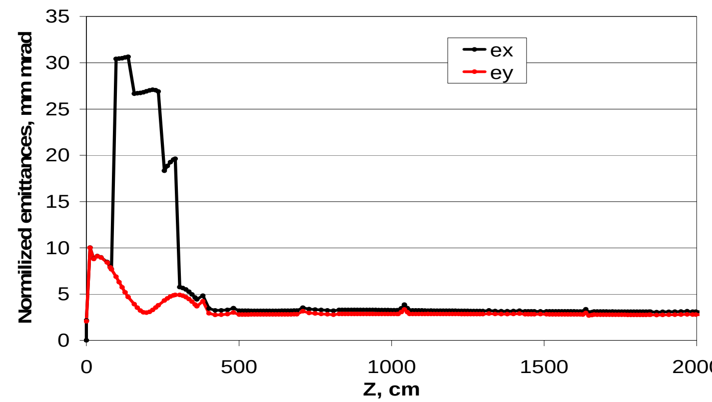
# A few examples – electron beam dynamics




MaryLie/Impact parallelized 3D code with 5th-order tracking.
X - Px phase space after tracking from exit of RF gun through last 5 cell RF cavity (MaryLie-Impact in green and Parmela in red). With Horizontal (X) random misalignments xrms errors of 0.5 mm applied to the bending magnets. V. Ranjbar et al, High-Order Modeling of an ERL for Electron Cooling in the RHIC Luminosity Upgrade




Evolution of the projected normalized transverse emittances rms in the test-bed system for beer-can distribution 5nC per bunch (final horizontal emittance black 3.1 mm mrad, vertical emittance red 2.8 mm mrad) D. Kayran et al, Optics of a Two-Pass ERL as an Electron Source for a Non-Magnetized RHIC-II Electron Cooler, THPAS096

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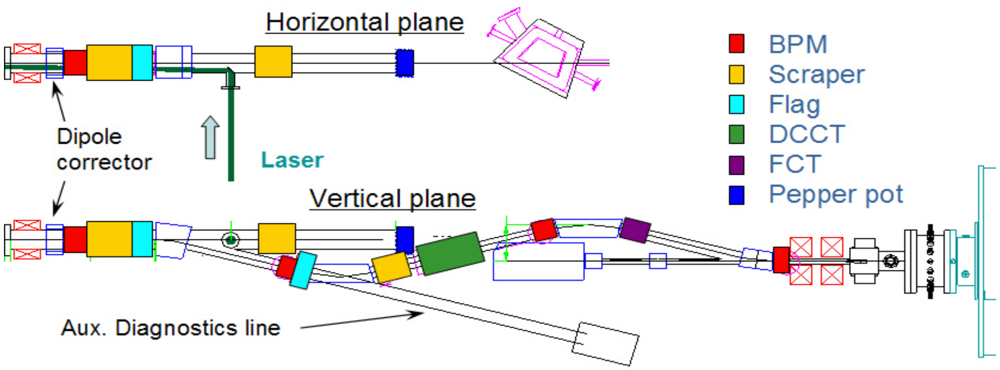
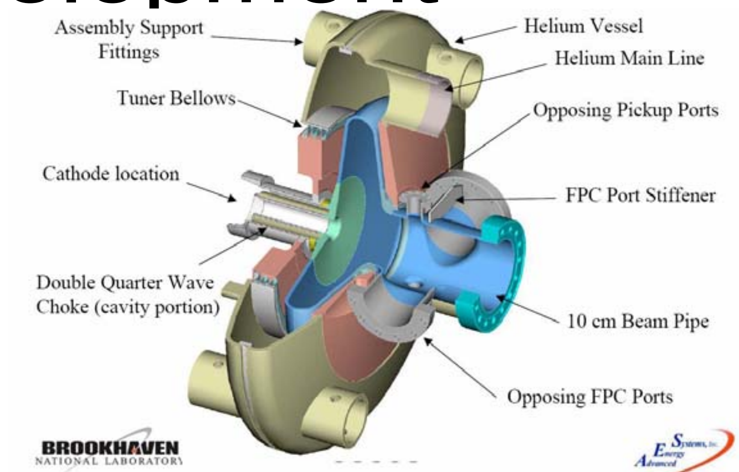
# What is ahead?

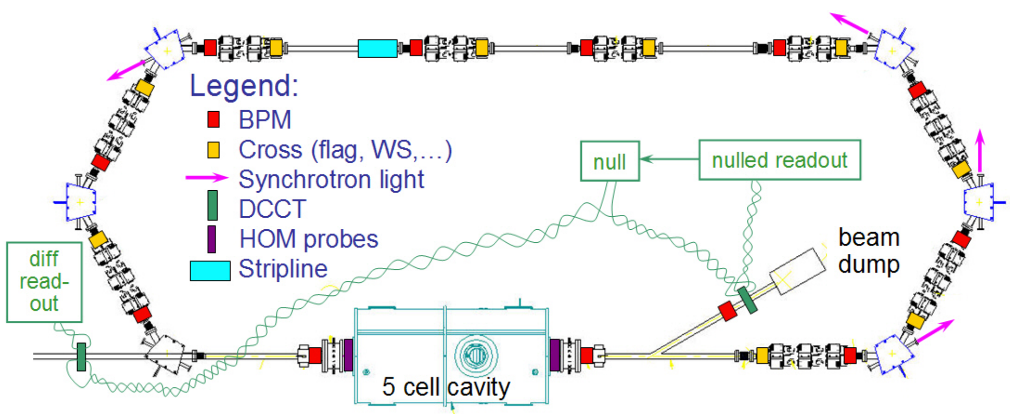
- The R&D program aims at the reduction of technical, budgetary and schedule risks through the demonstration of accelerator components
  - SRF photoinjector
  - high quantum efficiency photocathodes
  - high-current acceleration cavity
  - ERL beam merging system
- The components will be tested in an Energy Recovery Linac (ERL), scheduled to start commissioning in February 2009.

# A few examples – hardware development




Diagnostics for the R&D ERL.
Above: Gun-injection line. Below: ERL
E. Pozdeyev et al. Diagnostics of BNL ERL.
FRPMS116




A. Burrill et al, Challenges Encountered during the Processing of the BNL ERL 5 Cell Accelerating Cavity WEPMS088

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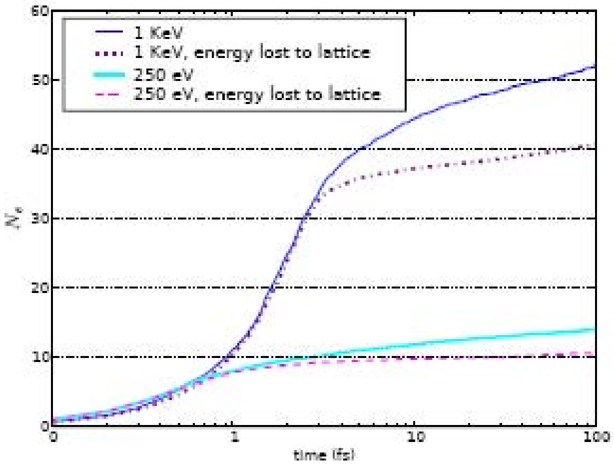
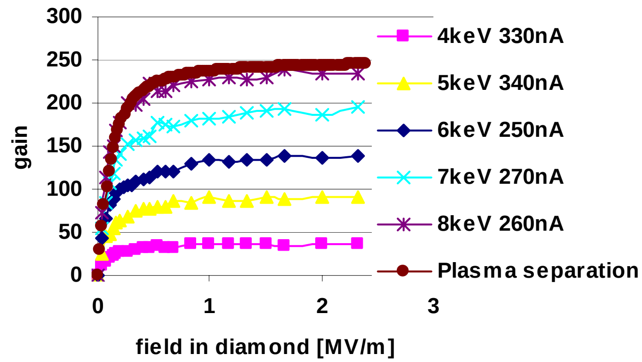
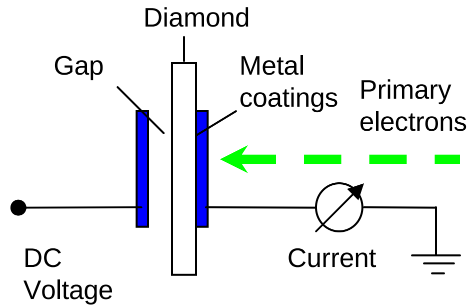
# A few examples – photocathode R&D

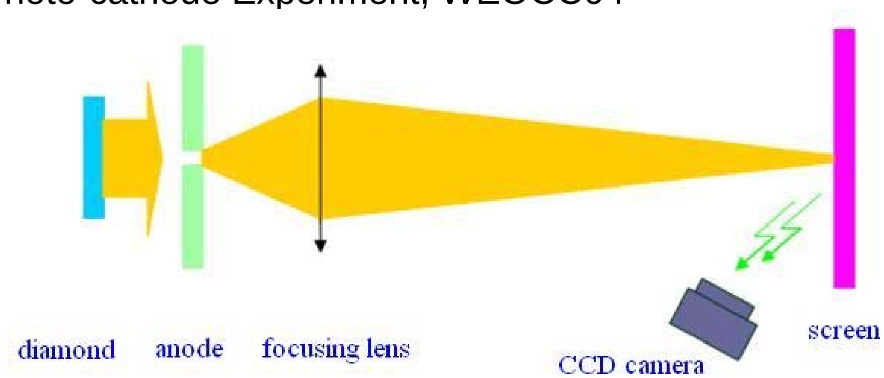



VORPAL simulation of the number of secondary electrons as a function of time following a primary impact. D. Dimitrov et al, 3D Simulations of Secondary Electron Generation & Transport in a Diamond. THPAS020



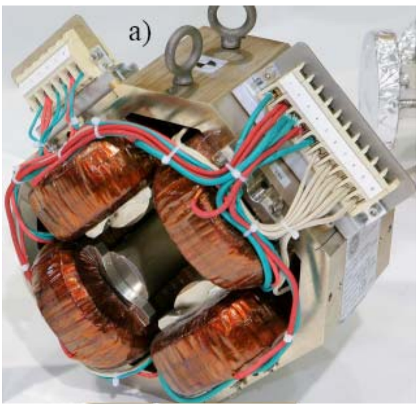



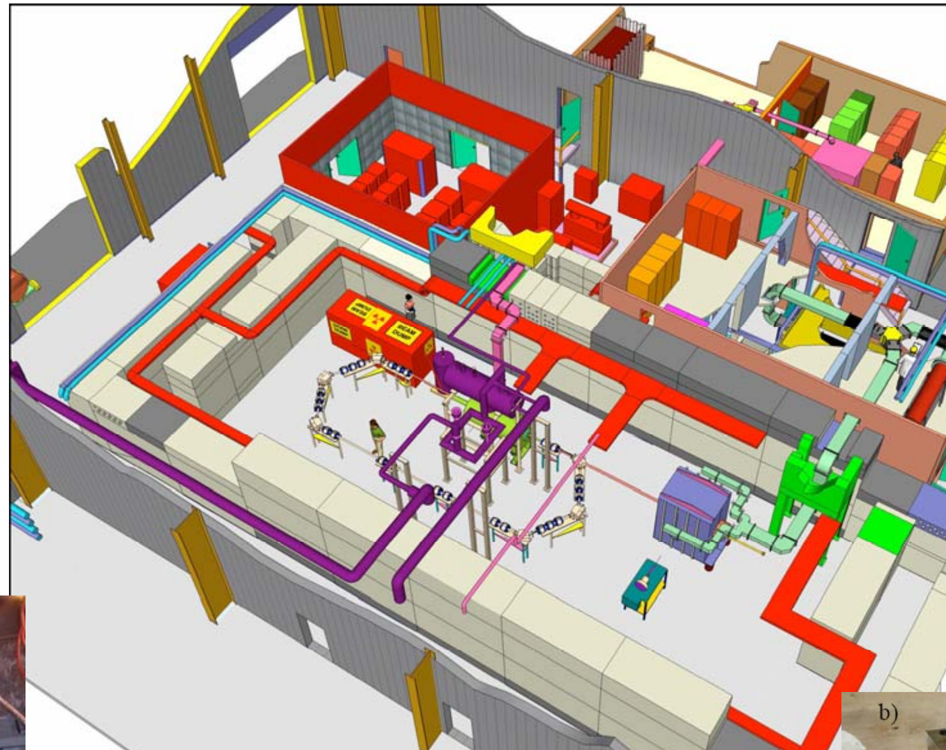

X. Chang et al, Recent Progress on the Diamond Amplified Photo-cathode Experiment, WEOCC04




Q. Wu et al, Thermal Emittance Measurement Design for Diamond Secondary Emission

# R&D ERL
# Commissioning 2/09




V.L. Litvinenko et al, Status of R&D Energy Recovery Linac at Brookhaven National Laboratory, TUPMS076

V.L. Litvinenko et al, Unique features in magnet designs for R&D Energy Recovery Linac at BNL MOPAS097

Thank you for your attention