# R&D ENERGY RECOVERY LINAC AT BROOKHAVEN NATIONAL LABORATORY *

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*Abstract*

Collider Accelerator Department at BNL is in the final stages of developing the 20-MeV R&D energy recovery linac with super-conducting 2.5 MeV RF gun and single-mode super-conducting 5-cell RF linac. This unique facility aims to address many outstanding questions relevant for high current (up to 0.5 A of average current), high brightness energy-recovery linacs with novel ZigZag-type merger. Recent development in the R&D ERL plans include gun and 5-cell cavity (G5) test and possibility of using R&D ERL for proof-of-principle test of Coherent Electron Cooling at RHIC [1].

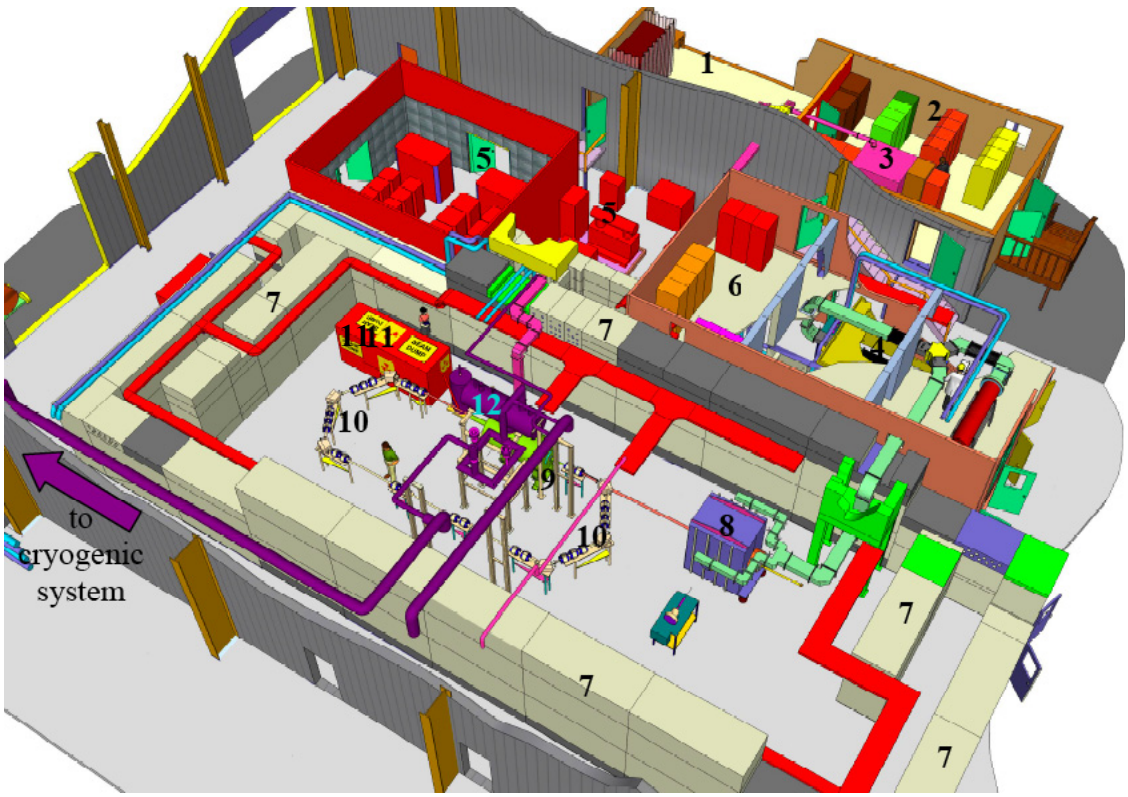


Figure 1. Layout of R&D ERL in Bldg. 912 at Collider-Accelerator Department, BNL: 1 – R&D ERL control room; 2 – diagnostic and control racks; 3 – 703.75 MHz, 50 kW CW RF transmitter; 4 - 703.75 MHz, 1 MW CW klystron; 5- 2 MW CW HV power supply for the klystron; 6 – power supplies and other electronics; 7 – shielded R&D ERL vault with removed roof beams; 8 – 2 MeV, 703.75 MHz SRF photo-injector; 9 – 20 MeV, 703.75 MHz 5-cell SRF linac; 10 – return loop; 11 – beam dump; 12- part of the 1.8 K$^{o}$ cryogenic system (most of the system is outside the picture).

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## ERL R&D PROGRAM AT BNL

R&D ERL, shown in Fig.1, will serve as a test-bed for future RHIC projects – ERL-based coherent electron cooling [1,2] and 10-to-30 GeV ERL for lepton-ion collider eRHIC [3,4]. It will also address more general issues expanding capabilities of ERLs: from novel SRF injectors [5], high current and high brightness beam ERL operation [6] and highly flexibility lattice [7,8] to enable covering a vast operational parameter space from non-achromatic lattice to achromatic with large range of $R_{12}$, $R_{34}$ and $R_{56}$ parameters. Main parameters we plan to attain with this ERL are listed in Table 1.

Table I. Parameters for the R&D ERL

| Mode: | High charge/current |
|---|---|
| Injection energy, MeV | 2.5 / 2.5 |
| Maximum beam energy, MeV | 20 / 20 |
| Average beam current, A, up to | 0.05/ 0.5 |
| Bunch rep-rate, MHz | 9.4 / 704 |
| Charge per bunch, nC | 5 / 0.7 |
| Normalized emittance, mm*mrad | <10/ ~2 |

Future RHIC upgrades define the goals for the R&D ERL development to test:

1. Key components of the coherent electron cooler
2. High Current ERL based on SRF technology
   - 703.75 MHz normal and polarized SRF gun with high CW current;
   - high current 5-cell SRF linac with HOM absorbers;
   - stability criteria for high CW beam currents.
3. Scalability for future linac-ring collider eRHIC with
   - 10-30 GeV SRF ERL;
   - possible SRF ERL-based FEL-driver for high current polarized electron gun;
   - attainable ranges of electron beam parameters in SRF ERL.

Majority R&D ERL of its elements are in hands and undergoing testing, measurements or installation. Few remaining elements (the most importantly SRF gun and driver-laser) are in the process of advance design, procurement or manufacturing. The commission of multiple ERL subsystem (1 MW klystron, 5-cell cavity, cryogenics, power supplies and magnets, diagnostics, SRF gun) started in 2007 and will continue into 2009 [5].

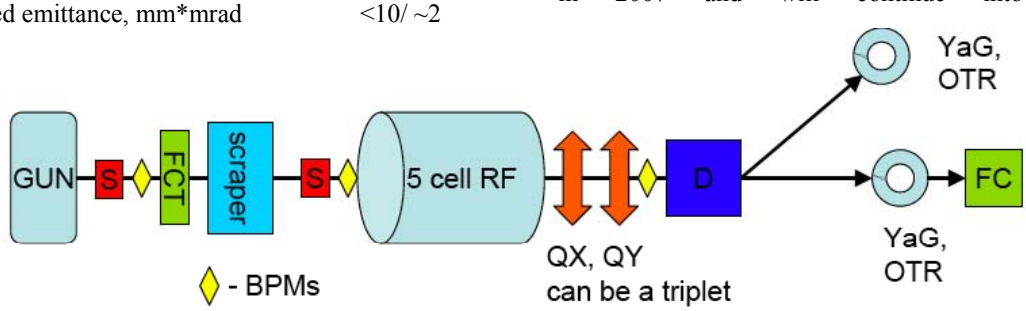


Figure 2. Layout of G5-test: 2.5 MeV electron beam from the SRF gun will propagate initially through a straight section with dedicated beam diagnostics- BPMs, YaG and OTR screens, fast current transformer and scraper. It will be accelerated in 5-cell cavity to 20 MeV and its parameters will be measured using dedicated diagnostics with and without dipole. The system is designed to measure both projected and slice emittances of the beam.

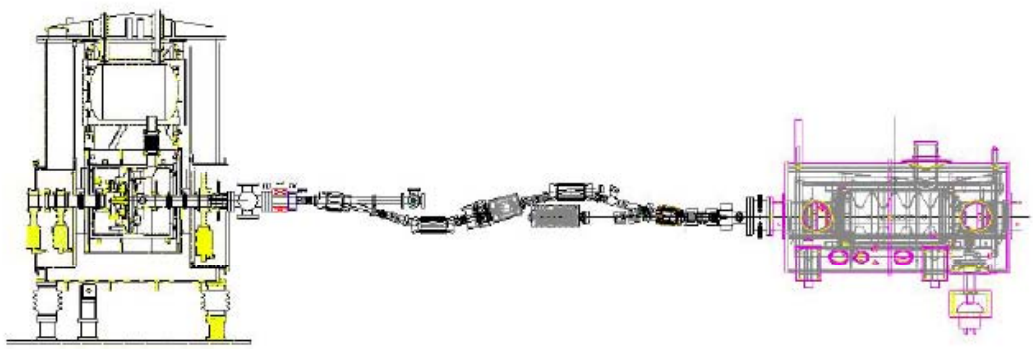

Figure 3. Left side of G5-test with the ZigZag merger installed. The diagnostic set-up is the same as in Fig.2.

Present plan calls for start the commissioning from gun & 5-cell (G5) cavity beam test (see Figs. 2 and 3) in 2009. This test is design to address the issues related to the ERL merger using full charge e-bunches with a low rep-rate Initially we will evaluate the performance of the G5 with the straight pass (2) and than we will install the ZigZag merger [6] into G5 system. Complete R&D ERL test in dedicated cave in Bldg.912 will follow the completion of the G5 test in 2010. After completion of the R&D ERL test program, majority of its subsystems will be relocated to IP2 of RHIC for proof-of-principle test of Coherent Electron Cooling [2]. Few elements of R&D ERL are shown in Fig. 4. The 5-cell SRF linac successfully went through vertical test at Jlab [9] demonstrating accelerating voltage in excess of 20 MeV/m. After finishing of the cryostat assembly, the cavity will go through a cold-emission test in the ERL cave,

Bldg.912. Its 50 KW power transmitter and cryogenic system are in place.

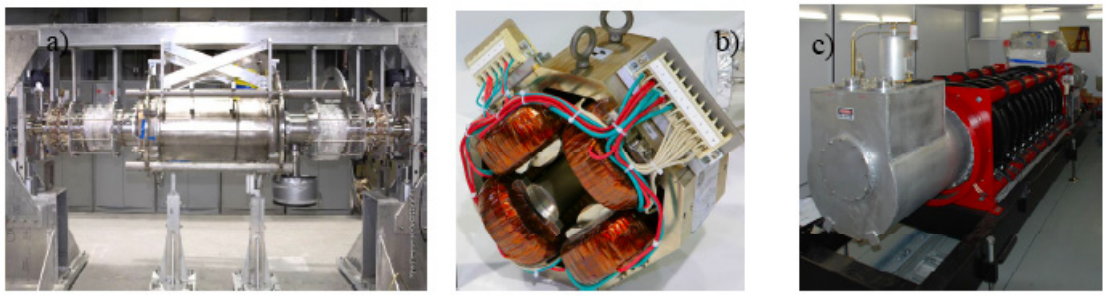


Figure 4. Some of R&D ERL subsystems: a) assembly of the 5-cell SRF cavity at BNL; b) one of 23 ERL quadrupoles; c) 1 MW CW 703 MHz klystron installed into 2" steel garage.

Among other systems in place are 1MW klystron (for SRF gun) with 2 MW DC GIBT power supply, circulator and dummy load, the cryogenic pump and ballast tank for the 5-cell cryostat, water-cooling system, shielded vault with PPS system, buildings for laser room, powers supplies and control room.

ERL-loop vacuum chambers (including dipole, quadrupole and BPM units) as well as all vacuum system controls and electronics are on hand. Magnetic measurements are completed for all ERL-loop quadrupole and dipole magnets [7]. Supports for ERL loop are also in hands. Multi-functional dipole magnets for the ZigZag merger were manufactured at BNL and are undergoing magnetic measurements.

The preparation chamber for SRF gun photo-cathodes has been redelivered to BNL and in the process of commissioning. The order for the laser system (needed for 5 nC, 9 MHz mode of operation) had been placed, the system now is in production and will be delivered to BNL in 2008. Many orders for ERL electronics and diagnostics [10] has been placed.

Few remaining designs are underway for new part of the G5 test, some elements of ejection system and the beam-dump beam line. There is a delay with placing some orders, which is caused by availability of funds. We expect to finalize remaining design and to place remaining orders for the R&D ERL in the next financial year.

The SRF gun is one of the most challenging part of the R&D ERL. The gun is designed and manufactured by AES, Medford, NY. We expect gun to be delivered to BNL in time for G5 test in 2009.

Overall, the R&D ERL at BNL makes steady progress toward its commissioning in 2009.

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