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Name: Mike Church

Authors: Mike Church[a)], Sergei Nagaitsev[a)], Yin-e Sun[a)], Philippe Piot[a),b)]

Institution(s): [a)]Fermilab, [b)]Northern Illinois University

Working Group: Discovery Science

A Facility for Accelerator Research and Education at Fermilab

Fermilab is currently constructing the "SRF Test Accelerator at the New Muon Lab" (NML). NML consists of a photo-emitted RF electron gun, followed by a bunch compressor, low energy test beamlines, SCRF accelerating structures, and high energy test beamlines. The initial primary purpose of NML will be to test superconducting RF accelerating modules for the ILC and for Fermilab's "Project X" – a proposal for a high intensity proton source. The unique capability of NML will be to test these modules under conditions of high intensity electron beams with ILC-like beam parameters. In addition NML incorporates a photoinjector which offers significant tunability and especially the possibility to generate a bright electron beam with brightness comparable to state-of-the-art accelerators. This opens the exciting possibility of also using NML for fundamental beams research and tests of new concepts in beam manipulations and acceleration, instrumentation, and the applications of beams.

Figure 1 is a photograph of the interior of NML as it exists today. Building infrastructure – cryogenics, electrical power, RF power, water cooling, electronics racks, shielding, etc. are currently being installed. A single SC cavity is currently under cooldown, and a single SCRF cryomodule is in the building and commissioning will commence this Fall. An electron gun will be installed and commissioned starting in 2/10. Beamline construction will start in late CY11 and we expect to start delivering beam in CY12.

Figure 1: Current interior of NML, looking downstream from the injector end.

The injector beamline is shown in Figure 2. It consists of a 1.3 GHz RF photo-emitted electron gun, followed by 2 SCRF accelerating cavities, a bunch compressor and beam diagnostics. The

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primary injector beamline will operate at ~40 MeV and is ~22 m in length. It will be capable of producing ILC-like beam structure: bunch charge = 3.2 nC, 3 MHz bunch repetition rate, bunch train length = 1 ms, 5 Hz bunch train repetition rate, and peak current in excess of >10 kA. Single bunch charge can be as high as 20 nC. In addition, there is floor space for 2 reconfigurable 40 MeV test beamlines for a variety of experiments.

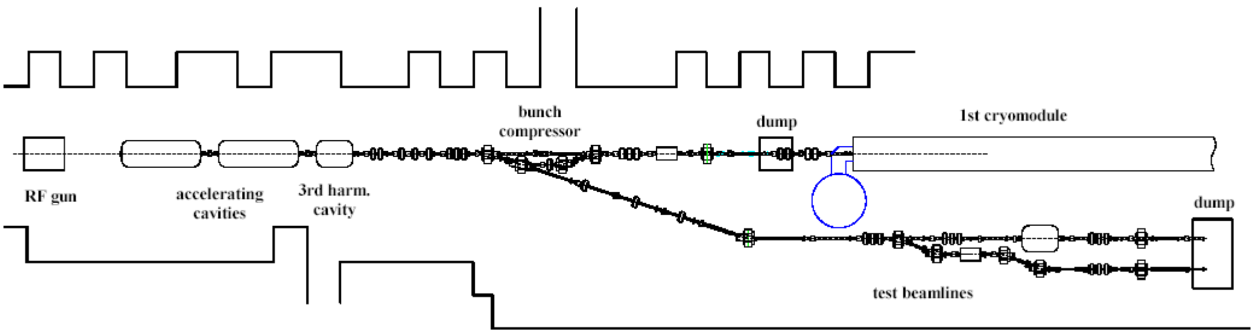

Figure 2: Injector beamline layout.

The acceleration section will initially consist of 3 ILC-type SCRF cryomodules, capable of accelerating beam to ~500 MeV. A building expansion, about to start, will allow for a total of 6 cryomodules and up to ~1400 MeV beam energy. A plan for the high energy downstream beamlines is shown in Figure 3. There will be floor space and infrastructure available for up to 3 high energy test beamlines (18 – 34 m in length) and a storage ring up to ~10 m in diameter. High energy dumps will absorb the 80 KW of beam power.

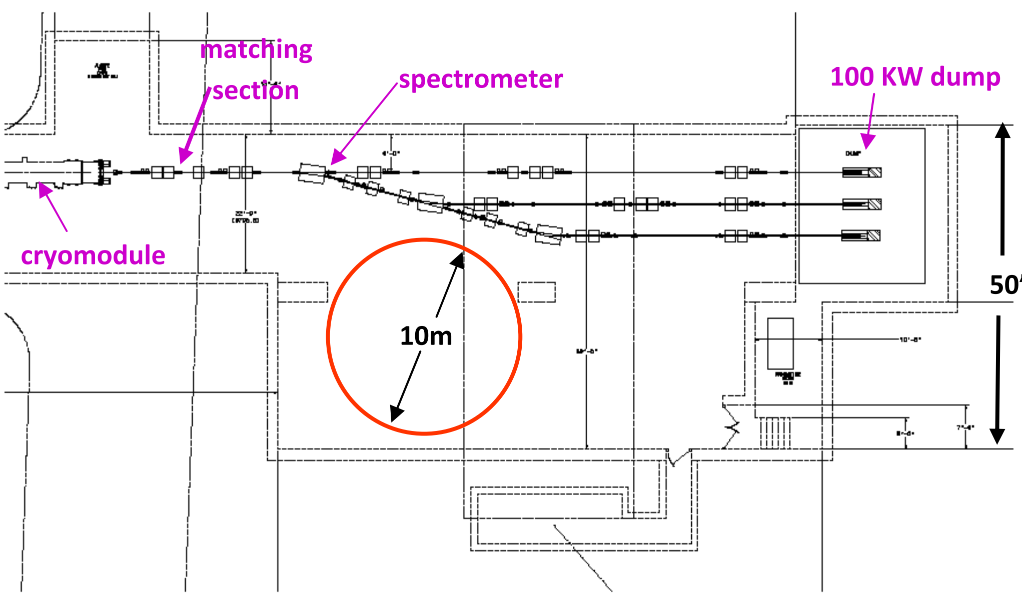

Figure 3: High energy beamline layout.

In May 2009, Fermilab hosted a workshop [1] to explore future directions of accelerator research at Fermilab. Half the agenda was devoted to fielding proposals for accelerator research experiments that might be performed at NML. Researchers from 7 different institutions presented a total of 19 proposals, ideas, and suggestions for interesting experiments that could be conducted here. This was the first introduction of NML to the community at large. We briefly outline some of the most attractive of these, and refer the reader to reference [1] for further proposals and background.

Table 1: An initial list of proposed beam experiments at NML.

Proposal	**Motivation/Application**	**Description**
optical stochastic cooling proof-of-principle (Valishev, FNAL)	possible use in μ storage ring; possible use in heavy ion storage ring	<u>Concept:</u> use wiggler as pickup and kicker for stochastic cooling at high frequency <u>Requirements:</u> ~750 MeV storage ring; λ=40 cm permanent magnet wiggler; Ti:Sa optical amplifier @ ~1 μm
test of integrable beam optics (Danilov, ORNL)	possible application to Project X and future proton storage rings	<u>Concept:</u> storage ring with highly nonlinear but stable betatron motion using nonlinear lenses <u>Requirements:</u> >300 MeV storage ring; flexible optics; 12.5 MHz RF
effect of power deposition in plasma on acceleration and focusing (Muggli, USC)	future linear collider	<u>Concept:</u> measure energy change and focusing of successive bunches in a plasma <u>Requirements:</u> 3.2 nC/bunch; 1.5 GeV; short bunches; 3 MHz bunch train; 20 μm spot size; 15 cm 10^{16}/cm^3 plasma; laser for interferometry
study ion motion in plasma (Gholizadeh, USC)	future linear collider	<u>Concept:</u> study ion motion in plasmas due to beam passage using Frequency Domain Holography <u>Requirements:</u> >2 nC/bunch; 1.5 GeV; 3 MHz bunch train; short bunches; ~20 μm spot size; 1 cm 10^{17}/cm^3 H plasma; 500 nm laser for holography
test of Image Charge Undulator (Piot, NIU)	compact x-ray source	<u>Concept:</u> study radiation from 2 parallel gratings <u>Requirements:</u> high peak current; short bunches; flat beam; emittance exchange for bunch train generation
test wakefield acceleration in dielectric slab structure (Piot, NIU)	test high gradient acceleration concept; extension of AWA work	<u>Concept:</u> study slab dielectric wakefields with bunch trains <u>Requirements:</u> high peak current; short bunches; ~20 μm spot size; flat beam (possibly); emittance exchange for bunch train generation

microbunching investigations (Lumpkin, ANL)	improve understanding of the fundamental phenomenon of microbunching; understand instrumentation effects;	Concept: compare microbunching between chicane and dogleg configuration; investigate microbunching phenomenon in regime of high charge and $60<\gamma<100$ Requirements: high peak current; short bunches; chicane and dogleg beamline configuration
Parametric Ionization Cooling lattice (Jansson, FNAL)	μ collider	Concept: build an electron model of a lattice suitable for μ cooling; investigate optics Requirements: adequate space in high energy beamline
test of 6-D μ cooling (Kaplan IIT)	μ collider	Concept: one of a number of cooling concepts can be investigated in a small μ storage ring; Requirements: ~300 MeV storage ring; e → μ production target
microbunch generation from slits (Sun, FNAL)	generation of closely spaced bunch trains for broad application	Concept: use emittance exchange with slit mask to generate closely spaced bunch trains Requirements: low energy beamline with emittance exchange setup
electroproduction of μ's at 1.5 GeV (Striganov, FNAL)	improved measurement of cross section; useful for a broad range of applications	Concept: this region of μ production has not been adequately measured; incorporate results into MARS model Requirements: μ production target; 1.5 GeV beam
development of compact μ source (Striganov, FNAL)	cargo inspection for homeland security; medical imaging	Concept: produce 10 MeV μ beam from 300 MeV e^- on 0.1 rad length tungsten target; Requirements: 1.5 GeV beam, μ production target; sweeping magnets
FBT and EEX tests in support of MaRIE (Carlsten, LANL)	proof of principle experiments for beam manipulations for proposed XFEL	Concept: test performance of various FBT and EEX lattices at ~1 GeV Requirements: adequate space in high energy beamline.

In summary, in addition to providing realistic tests of a new generation of RF cryomodules, the new NML facility offers excellent opportunities to advance accelerator science and technology on several fronts. NML will become a truly open users' facility with unique capabilities to advance accelerator research by groups from various Institutions, to enhance accelerator education and to promote accelerator technology development for industrial applications.

[1] Future Directions for Accelerator R&D at Fermilab, May 11–13, 2009, Lake Geneva, WI http://apc.fnal.gov/ARDWS/index.html