STATUS OF THE HZB ERL PROJECT bERLinPro*

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Abstract

The Berlin Energy Recovery Linac Project bERLinPro [1] is to be constructed at the Helmholtz Zentrum in Berlin. The aim of the project is to expand the required accelerator physics and technology knowledge mandatory for the generation of a high current (100 mA), high brilliance (norm. emittance below 1 mm mrad) cw electron beam.

Since the decision for full funding in October 2010 the project has entered a phase of detailed planning. Hardware specifications have been defined, various components have already been ordered, the building has been defined and construction will start in autumn 2014. First extensive tests of principal super conducting (sc) accelerator components have been successfully performed.

A summary of the most recent activities together with the details of the project time line for the coming years are given in this paper.

INTRODUCTION

The Helmholtz-Zentrum Berlin is operating synchrotron light facilities for more than 30 years. During this time a big effort has been made to improve the existing sources as well as to develop new concepts. One of the most promising ones is the Energy Recovery Linac (ERL), capable to accelerate storage ring like currents with linac like low emittances and short bunch lengths. In 2008 HZB submitted a proposal to build bERLinPro to the Helmholtz Association. In Oct. 2010 it was approved so that the project started officially in 2011.

bERLinPro's layout as a single-pass ERL is shown in Figure 1. Its 6.5 MeV injector consists of a 1.3 GHz SRF gun followed by a booster section with three 2-cell-cavities. The beam is merged into the main linac via a dogleg merger and accelerated by three 7-cell sc cavities to 50 MeV. Following the beam recirculation via a racetrack shaped magnetic lattice, the decelerated beam is dumped in a 650 kW, 6.5 MeV beam dump. Space is provided in the return arc to install future experiments or insertion devices to demonstrate the potential of ERLs for user applications.

A staged installation of bERLinPro is planned, initially focused on the development and successful operation of a high current SRF gun, followed by the demonstration of the full power injector operation (100 mA at 6.5 MeV). In a final stage the main linac and the recirculator will be installed and commissioned to demonstrate efficient energy recovery of a 50 MeV beam.

In the next sections status and progress of the various subproject groups will be presented.

SRF SYSTEMS

The sc accelerating structures are the projects key technology and thus technically the most challenging components. From the very beginnings much effort attempts have been made to gain experience in design, construction and operation of sc cavities. Initially HoBiCaT served as a testbed for the first gun prototypes - later on the testing and performance characterization of gun cavities will be shifted to GunLab [2]. To enable cavity treatment and assembly work at HZB a cleanroom of about 50 m^2 floor area, equipped with a high pressure rinsing has been built and will be operational in summer 2014. For vertical measurements a test stand for 2-cell cavities will be installed at HoBiCaT until the end of this year. A second one, capable to handle 9-cell cavities will be available in late 2016.

Gun Development and Testing

In collaboration with DESY and JLab two 1.6 cell gun cavity prototypes have been successfully tested at the HoBiCaT facility:

Gun-0.1 (Q1/2011): first prototype, with a lead coating on the back wall of the cavity

Gun-0.2 (Q4/2012 - Q1/2013): second prototype, with a lead plug inserted in the back wall of the cavity

Details of RF operation and beam measurements for both guns can be found in [3–5].

The 1.4-cell Gun-1.1 cavity, to be equipped with a load lock cathode insert system and a twin, cw optimized, medium power TTF-III coupler, has been fabricated by JLab in 2013 and is shown in Fig. 2. The welding was performed in 9/2013, followed by BCP cleaning procedures and vertical tests. Details are presented in [6]. The sc solenoid is delivered - most

Figure 2: Gun1 as assembled and tested in JLab in 2014.

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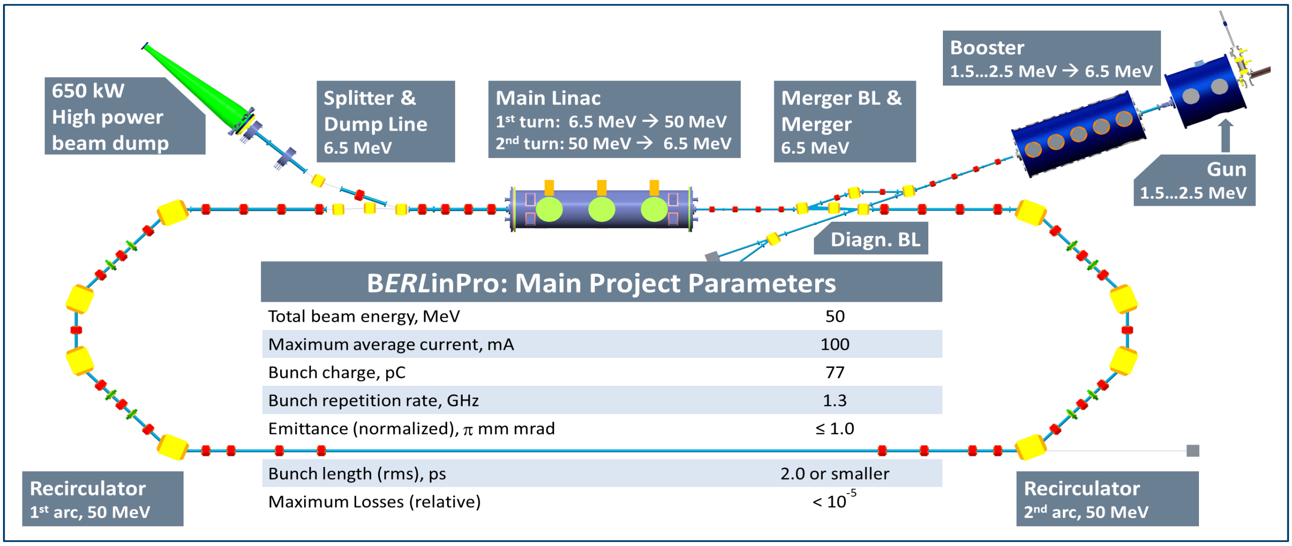

Figure 1: Draft of the major SRF and magnet components of bERLinPro with a summary of its main goal parameters.

of the other parts of the gun module are also ordered. Assembly will take place at HZB and start in summer 2015. First electrons from this gun, installed in GunLab, are expected in autumn 2015.

Experiences from Gun-1.1 operation will be incorporated in the final design of the Gun-2, equipped with two 130 kW couplers to generate currents up to 100 mA. It is expected to be ordered in summer 2016.

Booster

The design of the booster cavities and the booster module has been based on a design developed by Cornell University. A change in the power coupling has been implemented to provide sufficient power to accelerate a 100 mA beam. For bERLinPro two modified, horizontally mounted 130 kW KEK type couplers per cavity will be used [7]. The couplers RF design is near completion [8]. A high power test stand for conditioning will be assembled. The cavity cells are already produced and will be welded at JLab by the end of this year. The design of the module is near completion. First orders are planned for spring 2015.

Main Linac

The rf relevant design of the linac cavities is ongoing: the present layout is a 7-cell structure with a minimized HOM spectrum and waveguides for additional HOM damping [9]. For first tests a copper model will be built, as soon as the constructional and technical design is finalized.

WARM SYSTEMS

Optics & Theory

Linear Optics: the magnetic lattice is almost unchanged: an achromatic dogleg with three 20° bends merges the two beams upstream the linac. A racetrack shaped recirculator with two 180° arcs of four 45° bending and 15 quadrupole magnets each, guides the beam through the straight section and finally back to the linac entry. Currently a redesign of the dump line takes place in order to increase the distance between dump and linac, yielding improved vacuum conditions in the particle sensitive sc cavities. Trajectory correction simulations to prove the BPM/steerer concept and tolerance studies have been performed [10] as well as first estimates on the requirements of a machine protection system [11].

High Current Issues: Ion trapping simulations have been proceeded, on their base the number and distribution of clearing electrodes has been recently defined. Wake field & impedance studies are continued to define the impedance budget, identify critical structures and investigate influences on the bunch. Analytic calculations as well as extensive CST based numerical simulations are currently performed.

Magnets and Vacuum Components

Magnets: the magnets for bERLinPro will be manufactured by BINP, a contract has been signed in March 2014. A summary of the magnets ordered is found in Table 1. Beside the magnets also 23 girders, to mount magnet, vacuum and diagnostics components, are part of the order. A preliminary design review (PDR) will be held this June. The agreed delivery time is 9/2016.

Table 1: bERLinPro: Magnet Parameter and Number # of Magnets Ordered, Length: Iron only / Magnet incl. coil, Integrated Multipole Strength

Magnet type	#	Gap / mm	Length / cm / cm	$\int X ds$ X=B/g/m
Dipole / type I	8	52	20 / 29	23 mT m
Dipole / type II	1	82	20 / 30	12 mT m
Dipole / type III	8	52	52 / 70	131 mT m
Quad. / type I	12	52	10 / 16	75 mT
Quad. / type II	40	82	15 / 22	0.34 T
Sextupole	8	82	— / 22	8 T/m

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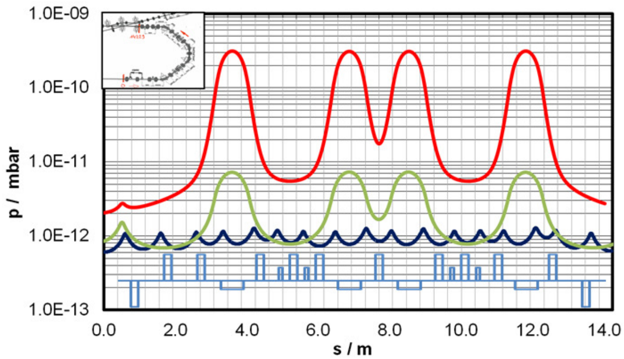

Figure 3: Pressure profile in the second recirculator arc. Dark blue: full NEG coating, red/green: dipole chambers without NEG coating and varied assumptions on the thermal out gassing rate, light blue: magnetic lattice.

Table 2: bERLinPro Time Line

2011	project start, first electrons from Gun-0.1
2012	machine redesign (100 → 50 MeV), CDR
2013	Gun-1.1 module design: ready & ordered, Machine layout fixed
2014	First photo cathodes, application for construction permits & **Ground Breaking**
2015	**First electrons from Gun-1.1** (GunLab), Booster & Gun-2 module ready & ordered, Low energy path subsystems ordered
2016	Linac module ordered, **Building ready for installation**, Low energy path: all components delivered & installed, **Start of Commissioning**
2017	Booster: CRYO & SRF commissioning, **First electrons from Gun-2 (GunLab)** and from **Gun-1 & Booster**
2018	GUN-1.1: I_{cw} > 1 mA, Start of Linac & Recirculator installation, **First electrons from Gun-2 & low energy path**
2019	Gun-2: I_{cw} > 10 mA, Linac & Recirculator: installed and commissioned, **Start of energy recovery & ERL physics program**

Vacuum System: The basic design is completed (beside the running modifications of the dump line, mentioned above).

Calculated pressure distributions confirm the SRF requirements when using steel chambers in the low energy parts (injector & dump line) and NEG coated aluminum at high energy for most of the recirculator vacuum components. Figure 3 shows exemplary the pressure profile in the second recirculator arc applying dipole chambers with and without NEG coating.

Beam Dumps: the high power dump, capable to sustain the 650 kW beam, was ordered in 12/2012. Its welding work has recently been completed. Now final assembly is ongoing, including the implementation of thermo sensors for temperature distribution control within the dump. The delivery is expected in 1/2015. For the second medium power dump (30 kW) a call for tender has been sent out in April 2014 - the order has already been made in the meantime.

bERLinPro BUILDING

For bERLinPro two buildings will be erected: the equipment hall in solid construction with about 1670 m^2 floor area and the accelerator hall with about 1100 m^2, covered by a 4 m soil layer as integral part of the radiation safety concept. The two building are in the execution planning, construction permit from building authority just arrived while that from the radiation safety is still awaited. First preparations of the area on the HZB site have already been started this spring, start of construction is scheduled for September 2014. The shell of the buildings will be ready in 1/2016, for 6/2016 they are planned to be the fully equipped.

TIME LINE

Table 2 gives an overview of major steps and milestones in design, construction and commissioning of the main bERLinPro components. The time line covers achievements reached in the past as well as those expected for the forthcoming project period.

REFERENCES

[1] A. Jankowiak et al. (ed.), "BERlinPro CDR", 2012, `http://www.helmholtz-berlin.de/projects/berlinpro/bpro-publication`

[2] J. Völker et al., "Introducing GunLab – A Compact Test Facility for SRF Photoinjectors", Proc. of IPAC2014, Dresden, Germany.

[3] A. Neumann et. al., "First Characterization of a Fully Superconducting RF Photoinjector Cavity", Proc. of IPAC2011, San Sebastian, Spain.

[4] A. Burrill et al., "RF measurement of the 1.6 cell Lead/Niobium photoinjector in HoBiCaT", Proc. of IPAC2013, Shanghai, China.

[5] M. Schmeißer et al., "Results from Beam Commissioning of an SRF Plug-Gun Cavity Photoinjector", Proc. of IPAC2013, Shanghai, China.

[6] A. Burrill et al., "Processing and Testing of the SRF Photoinjector Cavity for bERLinPro", Proc. of IPAC2014, Dresden, Germany.

[7] A. Neumann et. al., "Booster Cavity and FPC Design Issues for bERLinPro", Proc. of IPAC2014, Dresden, Germany.

[8] V. Khan et al., "High Power RF Input Couplers and Test Stand for the bERLinPro Project", Proc. of IPAC2014, Dresden, Germany.

[9] T. Galek et al., "BERLinPro Seven-cell SRF Cavity Optimization and HOMs External Quality Factors Estimation", Proc. of IPAC2013, Shanghai, China.

[10] B. Kuske et al., "Beam Positioning Concept and Tolerance Considerations for bERLinPro", Proc. of IPAC2014, Dresden, Germany

[11] S. Wesch et al., "Machine Protection Considerations for bERLinPro", Proc. of IPAC2014, Dresden, Germany.