

DESIGN OF A 40 MEV LINEAR ACCELERATOR FOR PROTONS AND DEUTERONS USING SUPERCONDUCTING HALF WAVE RESONATORS

M. Pekeler, K. Dunkel, C. Piel, H. Vogel, P. vom Stein
 ACCEL Instruments, Bergisch Gladbach, Germany, accel@accel.de

Abstract

The design of a medium energy ion linear accelerator (linac) for research applications is presented. The use of superconducting resonators allows continuous wave (cw) operation at high average currents. Independently phased RF supplies for each resonator give the ability to accelerate different particle species. The study gives an overview of the accelerator set-up and its subsystems.

Parameter	Value	Unit
Particles	Protons/Deuterons	
Energy	40	MeV
Current	4	mA
Operation	Continuously	

Table 1: Design specifications

1 LAYOUT

The basic design specifications as given in table 1 will be reached by a system consisting out of an ion source, a RFQ and several modules equipped with superconducting Half Wave Resonators (HWR). Starting at the ion source the particles are pre accelerated in a RF Quadrupole (RFQ) copper resonator up to an energy of 1.5 MeV/amu. The RFQ is capable of cw operation at an RF power level of approx. 220 kW. This transition energy of 1.5 MeV/amu between RFQ and the following superconducting accelerating modules was optimised in order to minimize the overall RF power consumption. The main part of the linac (figure 1) consists of 12 superconducting accelerator modules (figure 2), which accelerate the beam to its final energy of 40 MeV.

2 SUPERCONDUCTING MODULE

Each module contains four Half Wave Resonators (HWR) with an operating frequency of 176 MHz. The RF design is shown in figure 3. Two superconducting solenoid lenses with an field strength of up to 6 T are used for beam focusing. The resonators will be cooled by saturated liquid helium at 4.5 K.

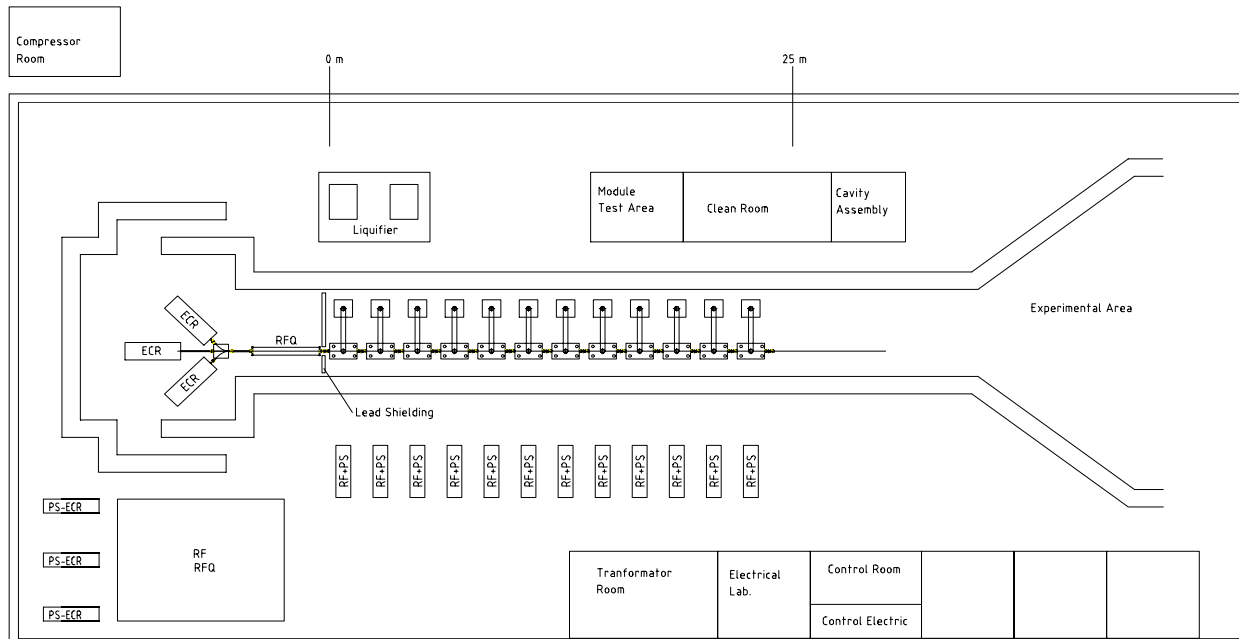


Figure 1: General layout

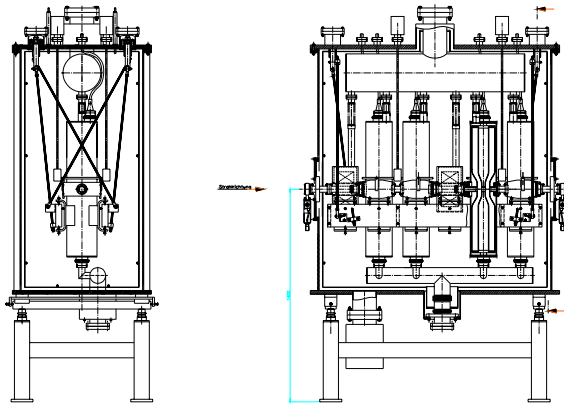


Figure 2: Layout of four HWR module

The average energy gain per resonator is approx. 800 keV. The corresponding RF peak surface fields in the resonator are 25 MV/m electric field and 60 to 80 mT magnetic field. For an average beam current of 4 mA the needed RF power per cavity is max. 4 kW.

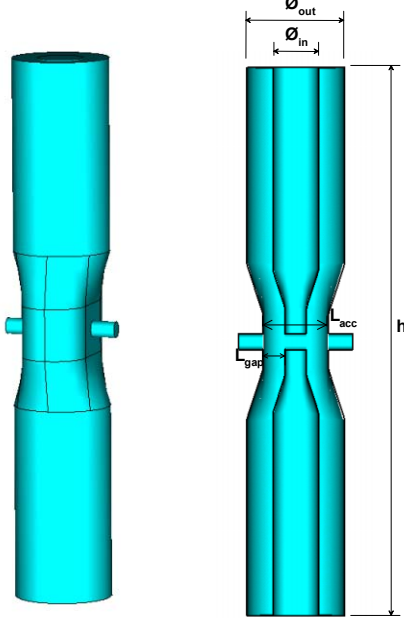


Figure 3: HWR design for RF field simulation

3 DESIGN

The first phase of the system design started with a beam dynamics analysis of different RF resonator types. A comparison between Quarter Wave Resonators (QWR), which are well established technology, and HWR showed a clear advantage of the HWR type with respect to its beam optical properties for acceleration of light ions [1]. Based on this resonator type a layout of the whole linac was established.

First results determined by single particle tracking in RF fields, as calculated by Microwave Studio, had been used to optimise transit time factors (figure 4).

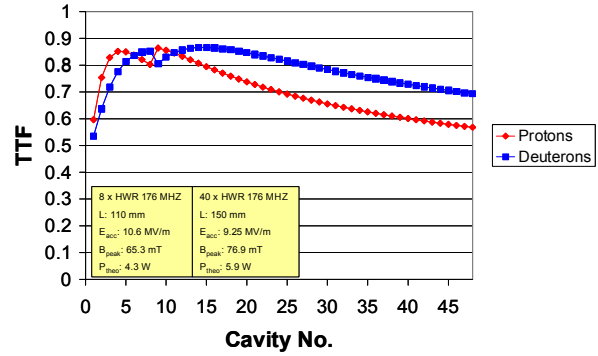


Figure 4: Transit Time Factors per cavity

The design is based on a peak electric field of 25 MV/m, the resulting energy gain per cavity is shown in figure 5.

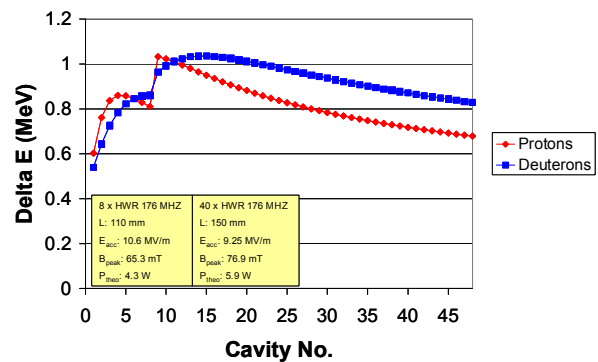


Figure 5: Energy gain per HWR

Figure 6 shows that already two HWR families optimised for different β are sufficient to reach 40 MeV. The use of 352 MHz spoke type resonators can improve the layout.

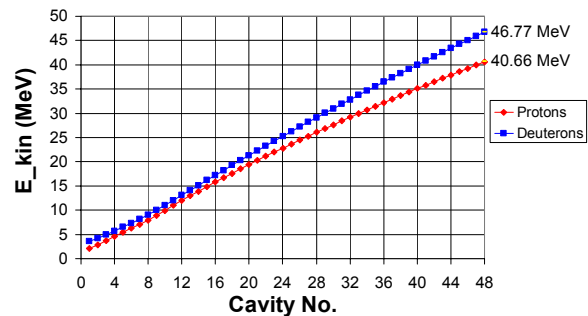


Figure 6: Particle energy

First multi particle simulations based on the simulation code TRACK [2] had been performed showing that an energy of above 40 MeV can be reached for protons and deuterons (figure 6 and 7).

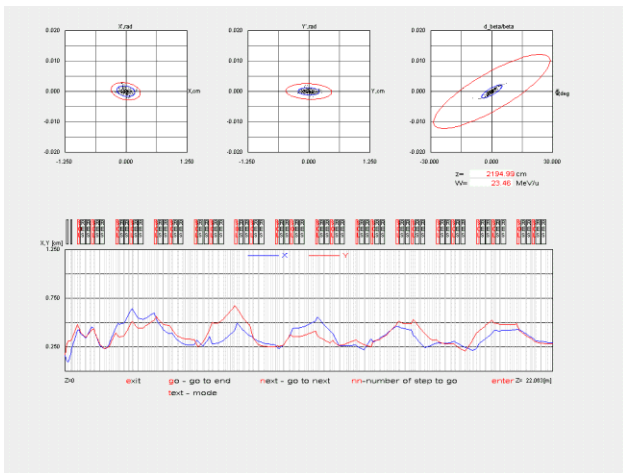


Figure 6: Simulation results for Deuterons

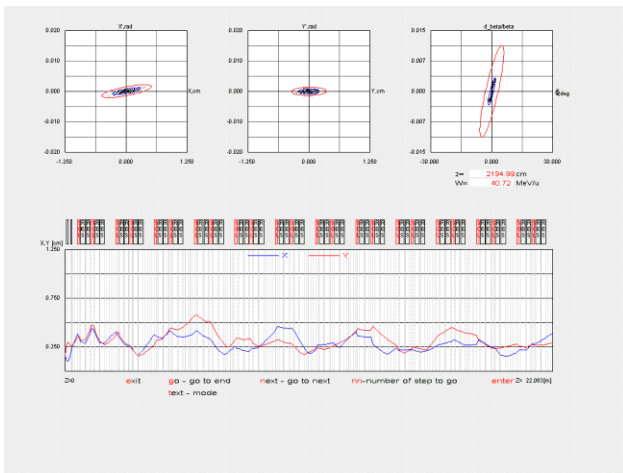


Figure 7: Simulation results for protons

4 RESULTS

Within this work a general layout for the 40 MeV linac based on sc HWRs was established. Based on RF simulations the transit time factors and energy gain per cavity were calculated, showing that particle energies above 40 MeV can be achieved with a total number of 48 cavities. All calculations are based on a peak electric field of 25 MV/m.

Cooling requirements at 4.5° K based on BCS theory were calculated (figure 8). According to operation experience of comparable systems [3] RF losses should be at or below twice the BCS losses up to the operating fields. With static losses of about 200 W the total refrigerator power needed amounts to 800 W at 4.5 K.

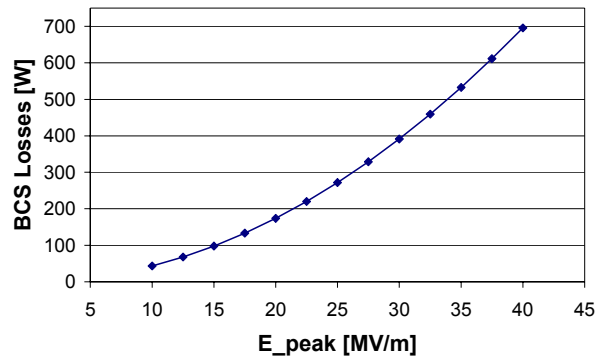


Figure 8: Cryogenic losses of linac with 48 cavities according to BCS theory

5 CONCLUSIONS

Based on the results it was shown that a 40 MeV proton and deuteron linac is feasible based on superconducting technology with an injection energy from a normal conducting RFQ as low as 1.5 MeV.

6 REFERENCES

- [1] A. Facco et al, "Study on Beam Steering in Intermediate- β s.c. QWRs", PAC'01, Chicago, 2001
- [2] P. N. Ostroumov, K. W. Shepard, "Correction of Beam-steering Effects in Low-Velocity Superconducting Quarter-wave Cavities" Phys. Rev. ST Accel. Beams, Vol. 4, 110101, 2001
- [3] J.R. Delayen et al., "Application of RF superconductivity to high-brightness ion-beam accelerators", Nucl. Instr. & Meth. B56/57, p.1025-1028, 1991