

THE DRIVER LINAC OF THE NEUTRON SOURCE FRANZ#

U. Ratzinger*, M. Basten, L.P. Chau, H. Dinter, M. Droba, M. Heilmann, M. Lotz, D. Mäder, O. Meusel, I. Müller, Y. Nie, D. Noll, H. Podlech, A. Schempp, W. Schweizer, K. Volk, C. Wiesner, C. Zhang, IAP, J.W. Goethe University Frankfurt, Germany

Abstract

This novel kind of neutron beam facility will provide 1 ns short neutron pulses with an approximately thermal energy distribution around 30 keV. The pulse repetition rate will be up to 250 kHz, the total proton number per pulse will be up to 6×10^{10} in the final stage, starting with a p – source current of 200 mA. A second target station will allow n – activation experiments by cw beam operation. An intense 2 MeV proton beam will drive a neutron source by the ${}^7\text{Li}(p,n){}^7\text{Be}$ reaction. The facility is under construction at the physics experimental hall of the J.W. Goethe – University. The 1m thick concrete tunnel was installed in 2009. In 2011 all rf amplifiers will be delivered and installed. Successful 200 mA proton source experiments in 2010 at a test stand will be followed by experiments on the 120 kV FRANZ terminal in 2011. The 250 kHz, 100 ns chopper in front of the rf linac is under construction, while the 2 MeV bunch compressor design was finished and the technical design of all components has started. The main accelerator cavity is under construction. First 2 MeV beam tests are expected for end of 2012.

INTRODUCTION

FRANZ is a project of the Goethe University Frankfurt [1]. It allows to intensify the well established accelerator research activities by providing very intense 200 mA proton beams with energies of 120 keV and at flexible pulse structure in the low energy beam transport section. Time dependent space charge compensation effects and beam – wall interaction phenomena can be investigated and optimized.

FRANZ is supported by GSI Darmstadt and by the Helmholtz International Center HICforFAIR, as it gives impact to the accelerator physics know how needed for the FAIR – project at Darmstadt as well as to the nuclear astrophysics research at FAIR. FRANZ will become a user facility for internal and external users.

New diagnostic concepts like tomographic optical beam measurement and analysis will be developed with the aims of controlling beam position, beam profile and finally – to derive the transverse beam emittance.

Due to the high pulse sequence of up to 250 kHz, the linac has to be operated in cw mode. At the envisaged beam currents a 2 MeV RFQ has been shown to be rather long and to consume a lot of rf power. That is why a coupled rf cavity was chosen finally, consisting of a 700 keV 4-Rod-RFQ and a 2 MeV IH – DTL. The total rf power losses will stay below 200 kW.

The 120 keV beam chopper together with the 2 MeV bunch compressor of the FRANZ facility will allow to reach novel proton peak current levels in the A – range at that low beam energy [2]. In the following the recent progress on key components will be described in more detail.

THE PROTON SOURCE

During 2010 source development on the 60 kV test stand resulted finally in a 220 mA dc beam with a proton fraction above 90 %. The beam perveance is $0.5 \text{ mA/kV}^{1.5}$. A magnetic filter field is applied near the plasma electrode to enhance the proton fractional content (Fig. 1). This is causing a vertical beam deflection of 1.7 deg at the current setup (Fig. 2).

Due to the complexity of a pentode extraction system and due to the uncertainty of the filter deflection angle it was decided to use a compact triode system for the 120 kV FRANZ - injector as shown in Fig. 1 and operated successfully at the test stand.

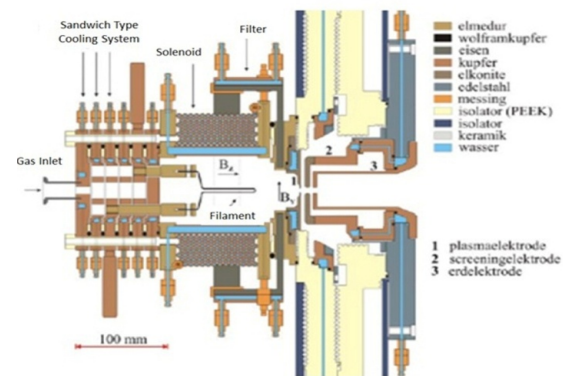


Figure 1: Scheme of the 200 mA proton source.



Figure 2: Photo of the 40 keV, 200 mA proton beam in front of the test stand Faraday cup (280 mm from extraction system).

Work supported by HIC for FAIR

* u.ratzinger@iap.uni-frankfurt.de

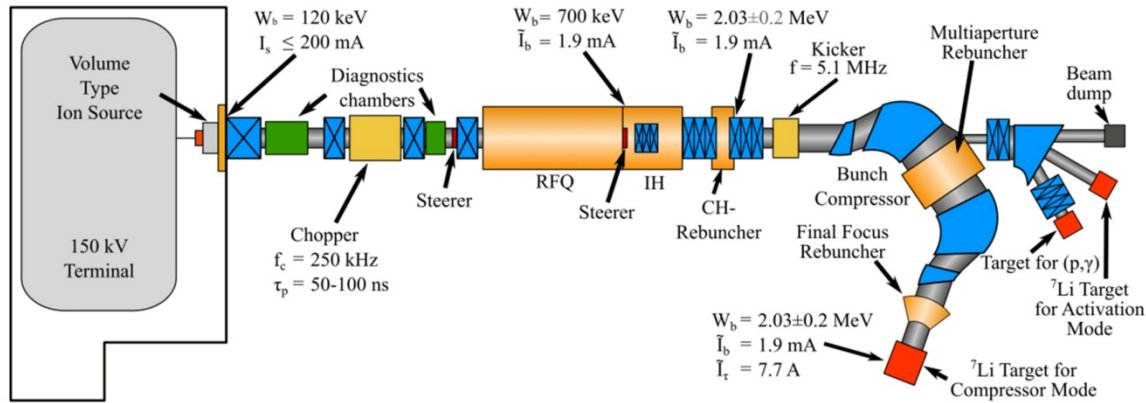


Figure 3: Scheme of the FRANZ proton driver linac with the two neutron production targets.

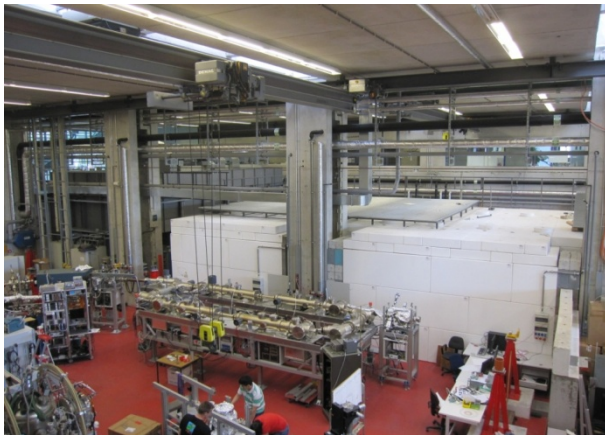


Figure 4: View on the FRANZ cave in the Frankfurt experimental hall. RF amplifiers will be installed on top of the roof.

LOW ENERGY BEAM TRANSPORT

Four solenoidal lenses provide the beam transport from the HV – terminal to the RFQ entrance (Fig. 3). Between lenses two and three the 250 kHz, 100 ns chopper will form pulses to feed the bunch compressor adequately. The chopper components are under construction, pretests with beam, especially on the electric deflector plates, are done in parallel. Up to 24 kW of beam energy have to be dumped and the vacuum chamber which is hit by quite a fraction of the beam during chopper ramps has to be protected against damage accordingly.

Preliminary beam tests along the LEBT with a small source at low beam energy have started already.

RFQ-DTL CAVITY AND REBUNCHER

After careful studies with CST – MWS [3] a simplified 1:2 scaled rf model allowed to investigate and to optimize the coupling geometry in detail [4]. The 4-rod-RFQ provides a large tuning range as every structure cell (Fig.5) can be fixed individually by a movable ground plate. This is an important feature to reach the needed

amplitude ratio between RFQ - and DTL – section in the end. The grounded drift tube between both sections (Fig. 5) houses an electromagnetic array, which can provide limited xy steering and quadrupole singlet action as might be required to match the beam into the DTL.

The IH – DTL starts with a 3 gap accelerating section followed by an internal quadrupole triplet and a 5 gap main acceleration section. The intermediate energy along the quadrupole lens is 1.0 MeV. The neutron energy spectrum can be shifted to higher energies by the 5 - gap rebuncher of the CH – type (Fig. 6), which follows after beam transport along a quadrupole triplet.

The beam envelopes from the RFQ – exit until to the compressor entrance are shown by Fig. 7.

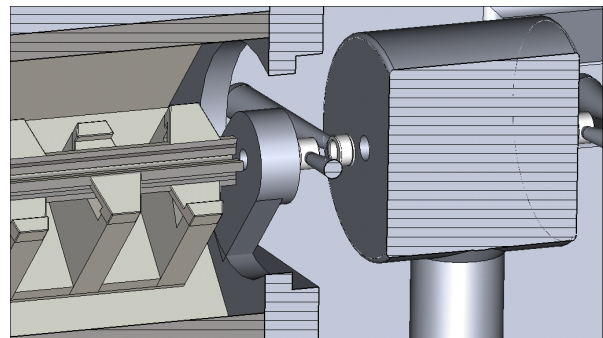


Figure 5: Coupling geometry between RFQ and IH-DTL.

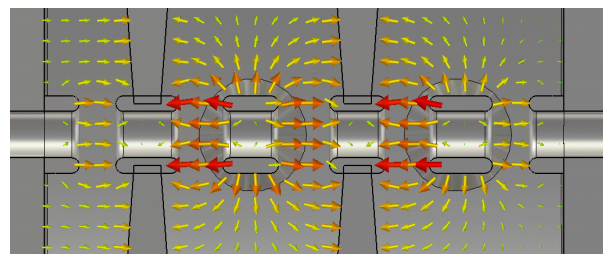


Figure 6: Electric field along the CH –type drift tube structure of the 2 MeV rebuncher (CST – MWS code).

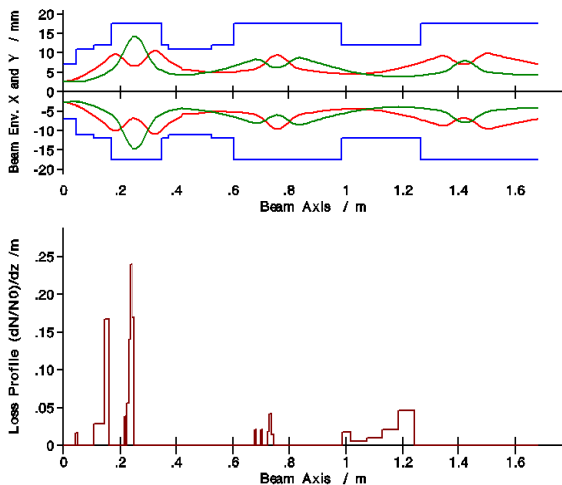


Figure 7: 95% beam envelopes along the IH-DTL (0 – 0.6m) and along the rebuncher (0.9 – 1.3m).

BUNCH COMPRESSOR

The bunch compressor [5] increases the peak current on the target by nearly one order of magnitude by merging 9 bunches from the linac down to the target (Fig. 8).

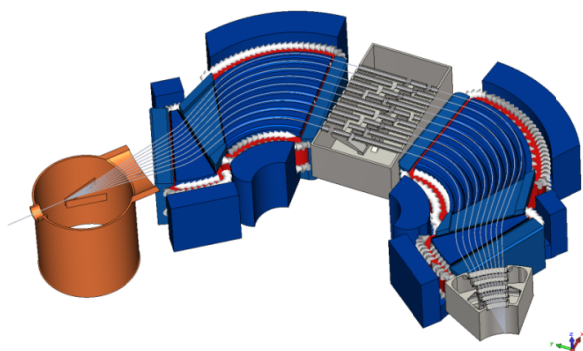


Figure 8: The 2 MeV bunch compressor. Nine bunches from the rf linac are transported to the target spot on paths of different length to create a 1 ns pulse. On the left the 5 MHz kicker cavity deflects the bunches horizontally. After penetrating two and four dipole magnets, the longitudinal bunch shape is refocused by a rebuncher cavity, to receive 1 ns bunch length at the target.

The kicker deflects each of the bunches onto its trace. Optimization of the magnetic system and of the two rebunchers [6] resulted finally in the need to generate individual deflecting angles as shown by Fig. 10

CONCLUSIONS AND OUTLOOK

The main components of the FRANZ driver are under construction. First neutrons are scheduled to be produced in the activation mode by a few mA cw beam – at the end of 2012. The bunch compressor will follow in a second stage. The original RFQ – electrode set will allow up to 50 mA current, while finally 140 mA are envisaged.

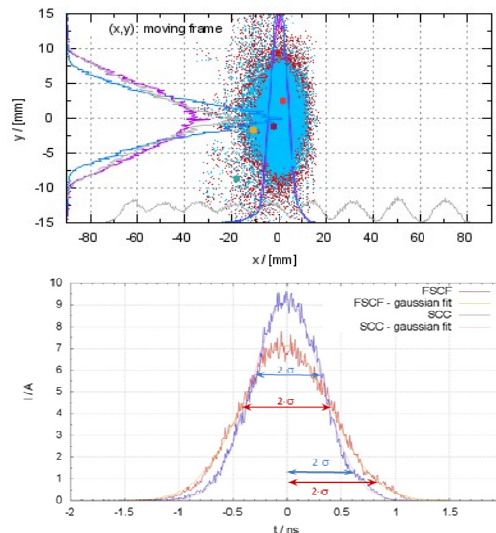


Figure 9: Bunch shape on target at 7 A peak current.

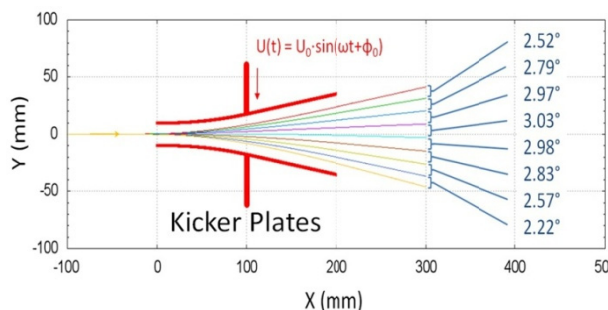


Figure 10: Kicker deflector plates and needed angles between individual bunch traces.

REFERENCES

- [1] U. Ratzinger, L.P. Chau, O. Meusel, A. Schempp, K. Volk, M. Heil, F. Käppler, R. Stieglitz, “Intense Pulsed Neutron Source FRANZ in the 1 – 500 keV Range”, Proc. ICANS-XVIII, April 2007, Dongguan, China, p. 210.
- [2] C. Wiesner, L.P. Chau, M. Droba, N. Joshi, O. Meusel, I. Müller, U. Ratzinger, “Chopper for Intense Proton Beams at Repetition Rates up to 250 kHz”, Proc. PAC09, Conf., Vancouver, p. 1500.
- [3] CST AG Darmstadt
- [4] M. Heilmann, D. Mäder, O. Meusel, U. Ratzinger, A. Schempp, “A Coupled RFQ-IH Combination for the Neutron Source FRANZ”, these Proceedings.
- [5] L. P. Chau, M. Droba, O. Meusel, D. Noll, U. Ratzinger and C. Wiesner, “Bunch Compressor for Intense Proton Beams”, Proc. Of the LINAC10 Conf., Tsukuba, p. 292.
- [6] D. Noll, L.P. Chau, M. Droba, O. Meusel, H. Podlech, U. Ratzinger, C. Wiesner, “Beam Dynamics of the FRANZ Bunch Compressor using Realistic Fields with a Focus on the Rebuncher Cavities”, these Proceedings.