THE FRANKFURT NEUTRON SOURCE FRANZ

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Abstract

An intense 2 MeV, 200 mA proton beam will drive a neutron source by the reaction $^7Li(p,n)^7Be$ on solid as well as on liquid lithium targets. The facility is under construction at the physics faculty new experimental hall in Frankfurt. To study in detail the nucleosynthesis of elements in stars by the s-process, a pulsed beam operation with a bunch compressor at the linac exit will offer several Ampere beam current within 1 ns pulse length and with 250 kHz rep. rate at the n - production target. As the upper limit of generated neutrons and the total n- flux at this source are well defined the sample for neutron capture measurements can be placed after a time of flight path as short as 0.8 m only. This will provide highest accessible pulsed neutron flux rates for neutron energies in the 1 - 500 keV range. The highly space charge dominated bunch forming process as well as the ion source, the rf coupled 175 MHz RFQ/DTL - resonator and the target development will be explained.

INTRODUCTION

Plans for FRANZ came up in 2005 when the new physics faculty building with its experimental hall became accessible. There is a great interest at Frankfurt in intensifying activities in nuclear astrophysics: On the one hand the FAIR facility at GSI Darmstadt will provide excellent experimental conditions to contribute to that field. On the other hand the idea came up to build a unique neutron generator at Frankfurt which will complement to FAIR by allowing neutron capture measurements with relevance to the s- and partly to the r-process of stellar nucleosynthesis. These experiments were done so far at FZK by F. Käppeler et al. using an electrostatic accelerator [1].

Facility	Neutron flux at sample position* [cm^{-2} s^{-1}]	Repetition Rate [Hz]	Flight path [m]	Pulse Width [ns]	Neutron energy range [keV]
FZ Karlsruhe	$1 \cdot 10^4$	250000	0.8	0.7	1-200
DANCE, Los Alamos	$5 \cdot 10^5$	20	20	250	th-10^5
n_TOF, CERN	$5 \cdot 10^4$	0,4	185	6	th-10^6
GELINA, Geel	$5 \cdot 10^4$	800	30	1	th-10^5
ORELA, Oak Ridge	$2 \cdot 10^4$	525	40	8	th-10^4
Elbe Dresden	$1 \cdot 10^5$	500000	3.7	0.4	50 – 10^4
FRANZ, Frankfurt	$1 \cdot 10^7$	250000	0.8	1	1-200 (500)

*Integrated flux between 1 keV and 100 keV

Figure 2: Comparison of the proposed facility with existing intense neutron sources.

FRANZ is designed to increase the neutron flux in the energy range from 1 – 500 keV by three orders of magnitude when compared to the former FZK setup [2-4]. It will be the most intense pulsed neutron source for the above mentioned energy range as shown by Figure 2. The neutron fluxes will allow to investigate neutron capture of radioactive isotopes with a total number of sample nuclei as low as 10^{15}. These may be produced at the nearby fragment separator S-FRS of FAIR at GSI Darmstadt.

Target station 1 will provide long pulsed and cw beams for sample activation and subsequent decay measurements at a separated detector area. Up to some 10^{11} n/s will be generated at that target, resulting in a flux of some 10^{10} n cm^{-2}s^{-1} at an activation sample.

Target station 2 on the contrary should deliver 1 ns short neutron bunches with rep. rates up to 250 kHz!

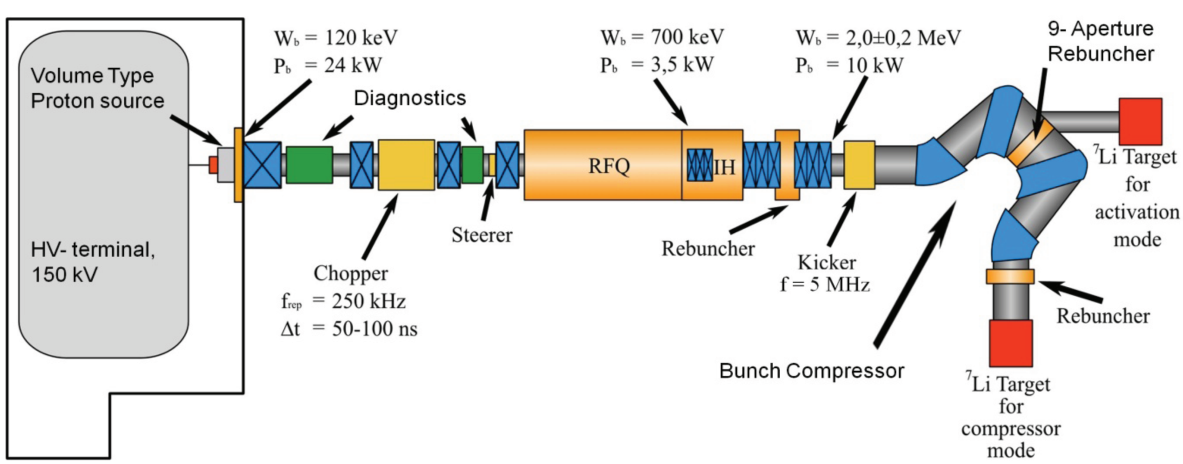

Figure 1: Scheme of the FRANZ proton driver with two target stations for neutron production.

After a drift of 0.8 m the neutrons will hit the sample which is positioned in the centre of a 4π BaF_2 Gamma calorimeter, received from FZK after shutdown of their very successful experiment.

FRANZ LAYOUT

A scheme of the proton driver is shown by Fig. 1. A filament driven 200 mA d.c. proton source has been developed and tested successfully at IAP. For FRANZ a compact 120 kV pentode extraction system was developed [5]. At present beam tests with the ion source on the test bench have started. There are still frequent voltage breakdowns within the extraction system. In a next step the pumping speed along the electrode array will be improved. Moreover, besides a one hole extraction also a three hole system will be studied in more detail.

The low energy beam transport LEBT includes four magnetic solenoids which have been installed already (Fig. 3). The rf linac will provide 2.1 MeV beam energy which may be varied by ± 0.2 MV in the following 5 gap rebuncher of the CH - type.

In case of the "activation mode" at target station 1 a cw beam at modest beam currents in the few mA – range will be used.

The most attractive and ambitious compressor mode will need chopping behind the second LEBT solenoid.

50 – 100 ns long beam pulses with rep. rates up to 250 kHz will be injected into the 2.3 m long 175 MHz rf linac in that case. 9 rf bunches of the bunch train after the linac will pass the Bunch Compressor on individual tracks and hit the neutron production target simultaneously within 1 ns. A solid Li target was developed successfully at FZK [6]. The key components will now be described in more detail.

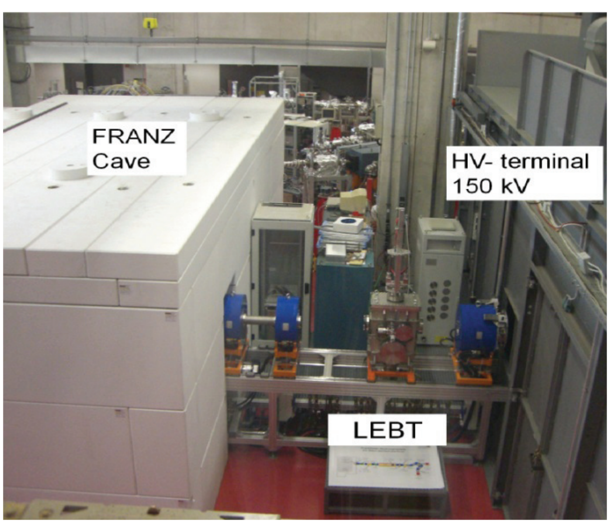

Figure 3: Photo of the HV-terminal, LEBT solenoids and FRANZ cave which will house the linac and experiments.

LEBT CHOPPER SYSTEM

A Wien filter array with a pulsed electric field will predeflect the beam by about 10 deg when the high voltage is switched off. This beam will then successively pass the main static septum magnet and hit the beam dump (Fig. 4). During the 100 ns, 12 kV pulse on the deflection plates the beam will be transmitted along the beam axis where the septum magnetic field is suppressed to the 1 mT - level. By that way 100 ns short beam pulses with a central flat top of 50 ns will arrive at the RFQ entrance.

The 12 kV, 100 ns, 250 kHz rep.rate high voltage supply has been developed and tested successfully at IAP Frankfurt. It is based on a commercially available THALES M2W AW transmitter equipment where the secondary circuits of the ring transformers where modified from low to high voltage.

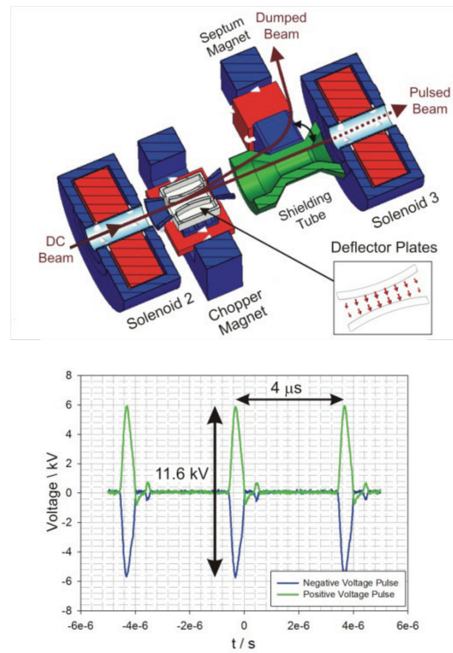

Figure 4: Chopper array (top) and achieved deflector pulse shape (bottom).

COMBINED RFQ - DTL CAVITY

Because of the high rep. rate the rf linac [7] has to be operated in cw. The high current load on the other hand can be neglected with respect to the rf power needs, as the energy per pulse into the beam is less than 40 mJ and can easily be provided by the stored cavity field energy.

The RFQ will accelerate the beam to 700 keV within a length of 1.6 m. The RFQ will be rf coupled to a 8 cell IH – DTL which will accelerate the beam to the final energy of 2.1 MeV. Within a total length of 0.7 m there will be a xy – steerer followed by three gaps, a magnetic quadrupole triplet and a 5 gap section (Fig. 5). The tube driven amplifier will provide up to 250 kW in cw operation. A scaled rf model will help to finally optimize the rf coupling and tuning between RFQ and IH-DTL. CST MWS – simulation results are quite promising: They favour a coupling just through a large diameter opening around the first drift tube housing the steerer. In that case no additional "galvanic" coupling might be needed.

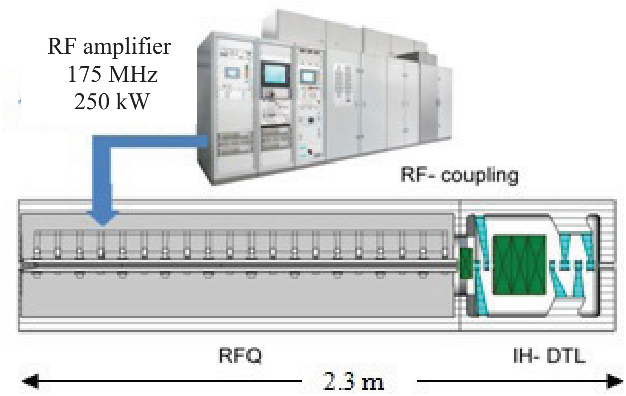

Figure 5: Coupled RFQ- DTL cavity with one feeder line.

BUNCH COMPRESSOR

After the linac the beam is passing a 5 gap rebuncher to match the beam longitudinally to the bunch compressor. Main differences to the classical Mobley – buncher are the micro bunch structure provided by the linac and the high space charge forces caused by up to $5 \cdot 10^9$ protons within each of the nine bunches which have to be merged into one 1 ns long bunch within a beam diameter of around 20 mm (Fig. 7).

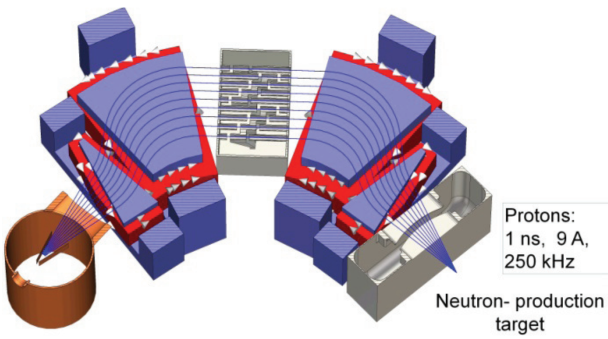

Figure 6: Bunch Compressor with 5 MHz kicker cavity at the left, and the final beam focus on the right.

CONCLUSION AND OUTLOOK

FRANZ has reached the construction phase. HV terminal, LEBT solenoids and cave were fabricated and installed already. The design of all key elements is close to completion. All 175 MHz and 87.5 MHz transmitters have been ordered in industry. FRANZ is expected to deliver first neutrons end of 2012.

Besides the future neutron experiments this facility will also allow attractive accelerator and beam research as well as a profound education of accelerator physicists.

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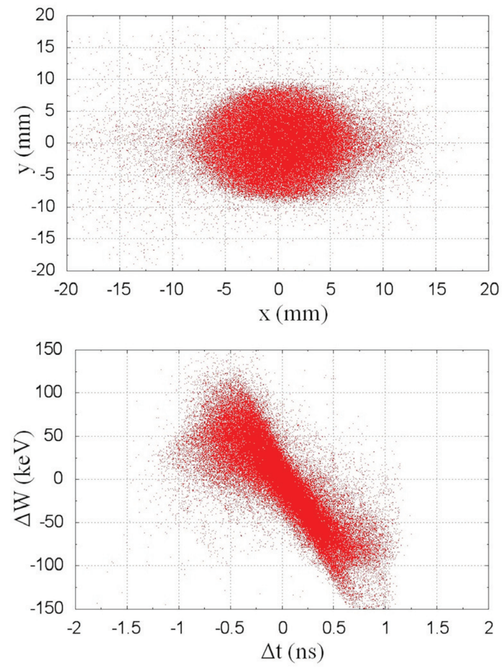

Figure 7: Beam profiles at the production target, 9 A beam current during 1 ns.

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