THE FRANKFURT NEUTRON SOURCE AT THE STERN-GERLACH-ZENTRUM (FRANZ)*

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Abstract

About 40ns long proton pulses with an energy of $120keV$ and currents of up to $200mA$ will be produced at the $150kV$ high current injector with a repetition rate of up to $250kHz$. The first part of acceleration will be done by a $175MHz$-RFQ. After this section the proton bunches will have an energy of about $1.0MeV$. A 5-gap-cavity will allow for an energy increase and for a variable end energy from $1.9MeV$ to $2.1MeV$. In order to get $1ns$ short pulses at the ^{7}Li-Target a buncher-system of the Mobley-Type [1] is proposed, whereby periodic deflection at one focus of a magnetic bending system guides the bunch train from the linac on different paths to the other focus, where the n-production target is located in the time focus. By $^7\text{Li}(p,n)^7$Be reactions low-energy neutron bunches will be produced with an averaged integrated flux-density of $10^7/(cm^2\,s)$ at a distance of $0.8m$. The upper limit for the neutron spectra will below $500keV$. The main challenge with respect to this buncher is the strong space charge interaction, which has to be treated by careful multi-particle simulations.

FRANZ is among other duties well suited for (n,γ)-cross-sectional measurements with astrophysical relevance [2]. It is characterised by high n-intensities, its $1ns$-pulse-structure and a very huge repetition rate up to $250kHz$.

This paper intents to motivate and to give a rough overview on the FRANZ project. In the first section the motivation for a pulsed high intensity keV neutron source is given. The following section gives a sketch of the FRANZ project, especially the concepts of the $1ns$-buncher-system. And finally the anticipated constraints are pointed out in the last section.

MOTIVATION

A powerfull neutron source with high intensities in the lower energy spectrum (see Tab.1) would allow attractive experiments also in many different fields of research, e.g. astrophysics, transmutation physics, biophysics, materials research and detector development.

Astrophysical Research

The different processes of the nucleo synthesis in stars are intensively investigated at the pressent [3, 4]. The most important processes are given by the s-process (slow neutron capture), the r-process (rapid neutron capture) and the p-process (photo-dissociation). The s-process is closely connected with the He-burning in a Red Giant. The resulting neutron spectrum is similar to the spectrum of $^7\text{Li}(p,n)^7$Be reactions. In a typical Red Giant regime the mean time for the neutron capture is in the order of one year. Due to the much smaller mean time of the β-decay the reaction path follows the valley of stability. Therefore the relative frequency of the emerging elements is proportional to the respective inverse (n,γ)-cross-section. Because of the limited neutron flux of the current machines a quantitative prediction with a needed accuracy of 1-3% is available for a small part of the reaction path. Especially the values for small and resonance-dominated cross-sections and for instable isotopes, which are responsible for branching of the reaction part, are not available. The analysis of such a branching point yield to inner physical parametres of stars without assumption of a special model.

The high intensity $^7\text{Li}(p,n)^7$Be-spectrum and the $1ns$ keV pulse structure of FRANZ is well suited for a more accurate analysis at a minimum of white noise. These results can help to complete the understanding of the nucleo synthesis of the universe since the Big Bang.

Transmutation and Materials Research

Another and also important task of FRANZ is to study the n-capture cross-sections of those elements more accurately, which are needed in materials for advanced reactor concepts. With these results the U- and Th-resources could use more efficiently, and especially the radioactive waste could be destroyed more effectively than with rapid neutron spectrum. Therefore the information of neutron-cross-section in keV-range is needed more than ever [5]. In addition to the approved materials some subcritical accelator driven systems use or plan to use quite new materials, for which the reaction cross-section are mostly or completely unknown [6]. In this task FRANZ could contribute some more accurate results because of its high neutron-intensities.

Detector Development

The institute of nuclear physics at Frankfurt (IKF) is involved in detector developements for large experiments like FAIR-CBM [7]. Not the time-structure but the high intensities are required for this task. It is possible to reach an integrated neutron flux of $10^8/(cm^2\,s)$ at FRANZ by using a compact configuration. With this provided intensities the Monolithic Active Pixel Sensor (MAPS) could be tested for their durability against non-ionising radiation.

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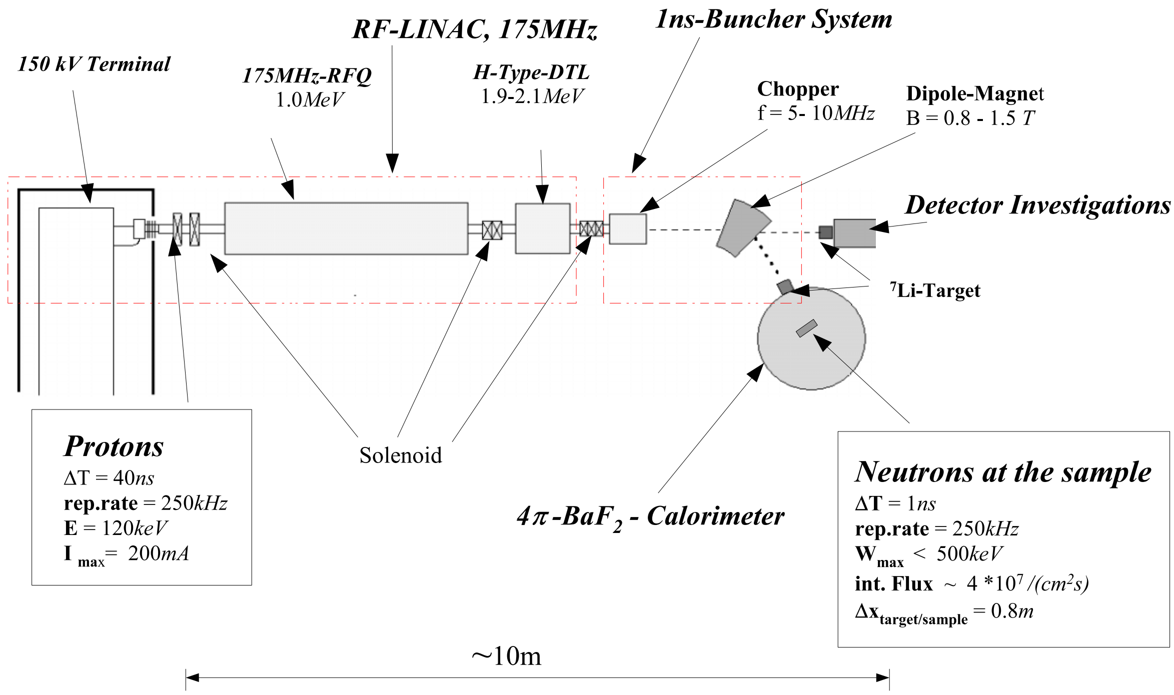

Figure 1: *Sketch of FRANZ. ΔT is the length of one macro bunch. The distance between the ^7Li-target and the sample is given by $0.8m$. The single bending magnet in this figure is just a symbol for a more complicated bending system. (see Fig.2)*

SKETCH OF FRANZ

FRANZ is consisting of a high current proton source on a $150kV$ platform, RF-LINAC and an $1ns$-buncher system (see Fig.1). A volume plasma source developed at IAP was sucessfully tested at p beam currents up to $180mA$ [8]. Therefor a DC extracted beam will be chopped at variable repetition rates up to $250kHz$ after passing the terminal voltage. About $40ns$ long beam pulse will be injected into the RF-LINAC.

IAP is experienced in designing and constructing of high current, low energy LINACs. The first stage will be a $175MHz$-RFQ, which gives the low energy $40ns$ proton bunches a micro structure and boosts them up to $1.0MeV$. This RFQ is discussed in detail in ref.[9].

In the second stage the macro bunches will be boosted by an energy variable H-Type-DTL up to a final energy between $1.9MeV$ and $2.1MeV$. Both possibilities are considered to use either the H_{110}- or the H_{210}-mode for this acceleration. The first option is the well known Interdigital H-type (IH) struture [10]. The second option would be a Cross bar H-type (CH) structure, which has been designed and studied at IAP/Frankfurt(Main) for several years [11].The final design of this structure could be similar to the CH-LINAC module for the FAIR p-LINAC[12].

Inspired by [1] an $1ns$-Buncher-System composed of a rf-chopper and *two* skew magnets with spatially varying magnet fields (see Fig.2) is proposed. Periodic deflection by the chopper at one focus of the bending system guides up to 7 bunches on different paths to the other focus, where

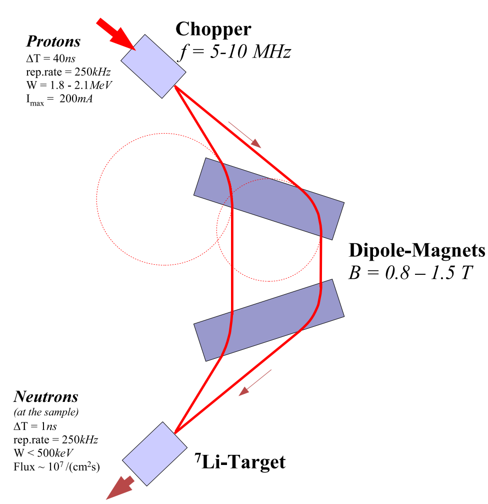

Figure 2: *$1ns$-Buncher-System. A bending system composed of two skew magnets with spatial non-constant magnet fields would have several advantages, e.g. more paramters in order to manipulate the beam dynamics, in average a greater distance between two bunches and a more compact geometry.*

a neutron production target is located. By choosing convenient paramater configurations all 7 bunches will arrive focusing in time at the target and produce an $1ns$ neutron bunch with in an intensity in the order of $10^7/(cm^2s)$ and at a repetition rate of $250kHz$.

By using two skew magnets we are free to vary the edge

Table 1: *target values of FRANZ compare with existing machines*

Facility *(location)*	**Nat.**	**int. n-flux at the sample** $[n/(cm^2s)]$	**repetition rate** $[Hz]$	**free path length** $[m]$	**pulse length** $[ns]$	**neutron energy** $[keV]$
FRANZ *(Ffm)*	D	$1{\cdot}10^7$	250 000	0.8	< 1	$1 - 200(500)$
FZ *Karlsruhe*	D	$1{\cdot}10^4$	250 000	0.8	0.8	$1 - 200$
DANCE *(Los Alamos)*	USA	$5{\cdot}10^5$	20	20	250	$therm. - 10^5$
n_ TOF *(Genf/CERN)*	CH	$5{\cdot}10^4$	0.4	185	6	$therm. - 10^6$
GELINA *(Geel)*	B	$5{\cdot}10^4$	800	30	1	$therm. - 10^5$
ORELA *(Oak Ridge)*	USA	$2{\cdot}10^4$	525	40	8	$therm. - 10^4$

angles for every micro bunch and the additional drift in order to control the beam dynamics in tranversal direction without larger effects to the total path length difference between the bunches. Further advantages of this concept are the greater distance between the bunches, when they pass the bending system, and a more compact geometry than the classical concept [1]. In this case the space charge interaction could be minimized.

Due to the close collaboration with FZ Karlsruhe FRANZ benefits from technology and hardware transfer concerning the neutron production target, the detector system and shielding materials. For a closer study on this topic we refer to [2].

CONCLUSION

The combination of a high current LINAC and a $1ns$-Buncher-System, which was never realized before, will allow for new experiments in various fields of research. The parameters of FRANZ are challenging. Especially the plasma generator, LINAC and the ^7Li-target system have to stand the high thermal loads. And the main challenge with respect to the buncher system is to treat the space charge interaction by careful multiparticle simmulations. FRANZ will be the main activity during the next four years within the recently founded Stern-Gerlach-Zentrum (SGZ) at the Frankfurt J.-W. Goethe-University.

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