National Centre for Accelerator based Research at GGV Bilaspur: Emerging facility for Neutron Generation

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Introduction

Accelerators have an important role to play in different fields of science and Technology including Nuclear Physics, Material Science, Biology, Medical usage, agriculture, food processing, etc. Apart from the use of accelerator for studying ion- solid interaction, neutron generation has emerged as an important field in recent years. This is due to growing applications of neutrons as an important tool in research including Neutron Activation Analysis (NAA). NAA have become very versatile technique for the measurement of neutron induced reaction cross-sections [1]. It is particularly powerful technology for filling up the wide gap existing in the neutron cross section data which are important for the design and development of new generation of reactors.

The measurement of cross sections of certain nuclear reactions at low energy is one of the major focus of experimental nuclear physics. Advances in accelerator technology coupled with state-of-the-art detection systems have significantly improved our understanding of the neutron activation analysis, neutron scattering and neutron production etc. In the present contribution, we shall discuss the salient features of low energy high current Pelletron accelerator being commissioned in this centre that is ideally suited for neutron activation analysis due to its capability of producing relatively high neutron flux.

Salient Features of the Accelerator Facility at GGV, Bilaspur

A 3.0 MV Tandem Accelerator (Pelletron 9SDH-4) based facility will be commissioned at Guru Ghasidas Vishwavidyalaya, Bilaspur (C.G) by the end of this year. The facility vig. **National Centre for Accelerator based Research (NCAR)** is a flagship program for providing state of the art research facilities on the campus in the areas of Nuclear Physics, Material Science Nanotechnology, Environmental Sciences, Life Sciences, Biotechnology, and Radiation Biology. It includes ion beam analysis techniques such as RBS, PIXE, NRA, RDA, and low (keV) and high energy (MeV) range ion implantation.

The accelerated positive ions from the pelletron can be delivered to one of three beam lines (i) MeV ion implanter at the end of the -10° beam line and (ii) an RC43 RBS End Station equipped with detectors for PIXE, NRA, ERDA and channeling for ion beam analysis as well as ion irradiation facilities at the 20° port of the analyzing magnet. A third beam line at the 0° port of the injector magnet will be used for low energy high current proton beam for neutron generation. The analyzing magnet has 9 ports, out of which (i) 0° port (ii) ±10° ports with ME/Z^2 = 310 amu-MeV, and (iii) ±20° ports with ME/Z^2 = 78 amu-MeV will be used presently. For the ion implantation beam lines, typically Silicon targets would be used for implantation. For ion beam analysis beam lines, targets can vary from light targets like carbon to much heavier ones depending on the application.

In the low energy Pelletron accelerator two types of ion sources (SNICS-II and TORVIS) will be available to produce negative ions for the acceleration in accelerating tank. The TORoidal Volume Ion Source (TORVIS) is based on the production of plasma in cylindrical discharge chamber followed by a Rubidium charge exchange cell for negative ion production. The strong TORVIS source will be used for production of protons and alpha particle with relatively high beam current. The following table gives the available beam currents for different ions species after acceleration through tandem at maximum terminal voltage.

9SDH-4 PERFORMANCE

Target beam currents (electrical μA) for a given charge state and approximate energy at 3MV terminal voltage**

	Injected Ion	6 MeV +1	9 MeV +2	12 MeV +3	15 MeV +4	18 MeV +5	21 MeV +6	24 MeV +7	27 MeV +8	30 MeV +9	33 MeV +10	36 MeV +11	39 MeV +12
^{1}H	H^-	50.0	-	-	-	-	-	-	-	-	-	-	-
^{4}He	He^-	8.5	10.0	-	-	-	-	-	-	-	-	-	-
^{7}Li	Li^-	0.65	2.22	1.50	-	-	-	-	-	-	-	-	-
^{10}B	B^-	1.69	9.40	11.07	1.41	0.020	-	-	-	-	-	-	-
^{10}B	BO^-(3MV)	10.0	24.0	10.2	1.00	-	-	-	-	-	-	-	
^{12}C	CN^-(3MV)	0.85	4.80	3.30	0.36	-	-	-	-	-	-	-	
^{12}C	C^-	4.47	22.5	62.1	22.0	9.00	0.018	-	-	-	-	-	-
^{14}N	NH_2^-	1.1	4.40	4.20	2.00	-	-	-	-	-	-	-	-
^{14}N	CN^-	0.65	6.50	8.32	2.50	0.050	-	-	-	-	-	-	-
^{15}N	CN^-	-	2.03	1.94	0.352	-	-	-	-	-	-	-	-
^{16}O	O^-	10.0	26.0	38.3	34.0	6.00	2.10	0.399	0.14	-	-	-	-
^{19}F	F^-	0.5	6.00	27.0	14.8	3.50	0.300	0.028	-	-	-	-	-
^{23}Na	Na^-	0.006	0.032	0.036	0.032	0.0050	-	-	-	-	-	-	-
^{28}Si	Si^-	3.3	32.0	60.0	36.0	6.50	1.98	2.03	0.88	-	-	-	-
^{31}P	P^-	-	20.0	22.2	10.0	5.00	-	-	-	-	-	-	-
^{58}Ni	Ni^-	0.9	33.0	55.5	12.8	7.00	3.18	1.33	0.56	0.198	0.080	0.044	-
^{90}Zr	Zr^-	-	-	0.30	0.12	0.100	0.018	-	-	-	-	-	-
^{197}Au	Au^-	*	47.5	30.0	14.5	5.50	2.70	0.91	0.250	0.080	0.030	0.0286	0.0264

The high proton beam current available ~ 50μAmp at 6 MeV, in fact is the highest in any accelerator of this class in the country and will open up many new avenues for research in low energy Nuclear Physics, especially for neutron generation. The facility is capable of providing neutron flux which is higher than available in presently installed system such as FOTIA at BARC. The upcoming facility is aimed to initiate neutron related activities along with the flagship research program.

Neutron Generation & NAA

Investigation of neutron-induced activation cross-sections is gaining considerable interest due to their potential applications in nuclear technology, dosimetry, nuclear medicine, industry apart from the Nuclear Physics. Estimated reaction cross-section measurements are extremely important for the advancement in reactor technology. A large number of target nuclides are known for which measurements of cross-sections with the neutron activation technique are available [2] and provide easy access to a variety of reaction channels. These tasks require improved nuclear data and higher precision cross-sections for neutron induced reactions. Keeping this in view, the extension of research facility for neutron generation has been decided at the Centre and the zero degree beam line will be extended for a review of precise measurement of various neutron induced reaction cross-sections. The planned neutron generation facility is shown in Fig 1.

An accelerator can be used for the production of neutron beam using nuclear reaction and sources of this kind have been used a great deal in neutron research. In the facility, $^{7}Li(p, n)$ reaction will be mainly used for generating mono energetic source of neutrons to produce high neutron flux.

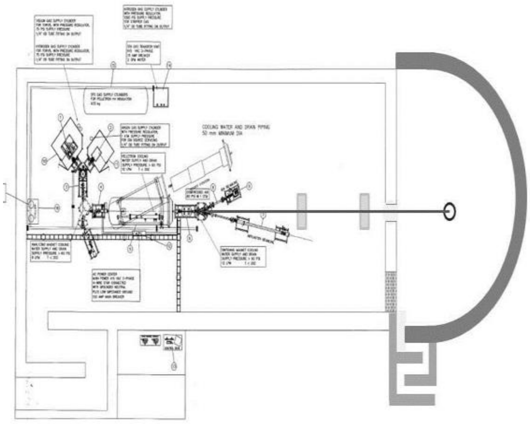

Fig. 1 Planed facility for neutron generation using 3MV pelletron accelerator

The present 3.0 MV Pelletron accelerator is capable of producing high neutron flux ($4.5x10^{9}$ neutrons/cm^{2}/sec) as it has high proton beam current of ~50μAmp. This provides the unique opportunity for neutron-activation cross sections measurements especially in low energy region where very limited information are available. Further, this facility will provide plate-form for low energy nuclear physics community for extensive studies in the areas related to nuclear astrophysics, neutron-induced reactions, measurements of neutron scattering cross sections, sub-barrier fusion reactions.

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References

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