High Power Beam Dump and Neutron Sources for SARAF Phase II

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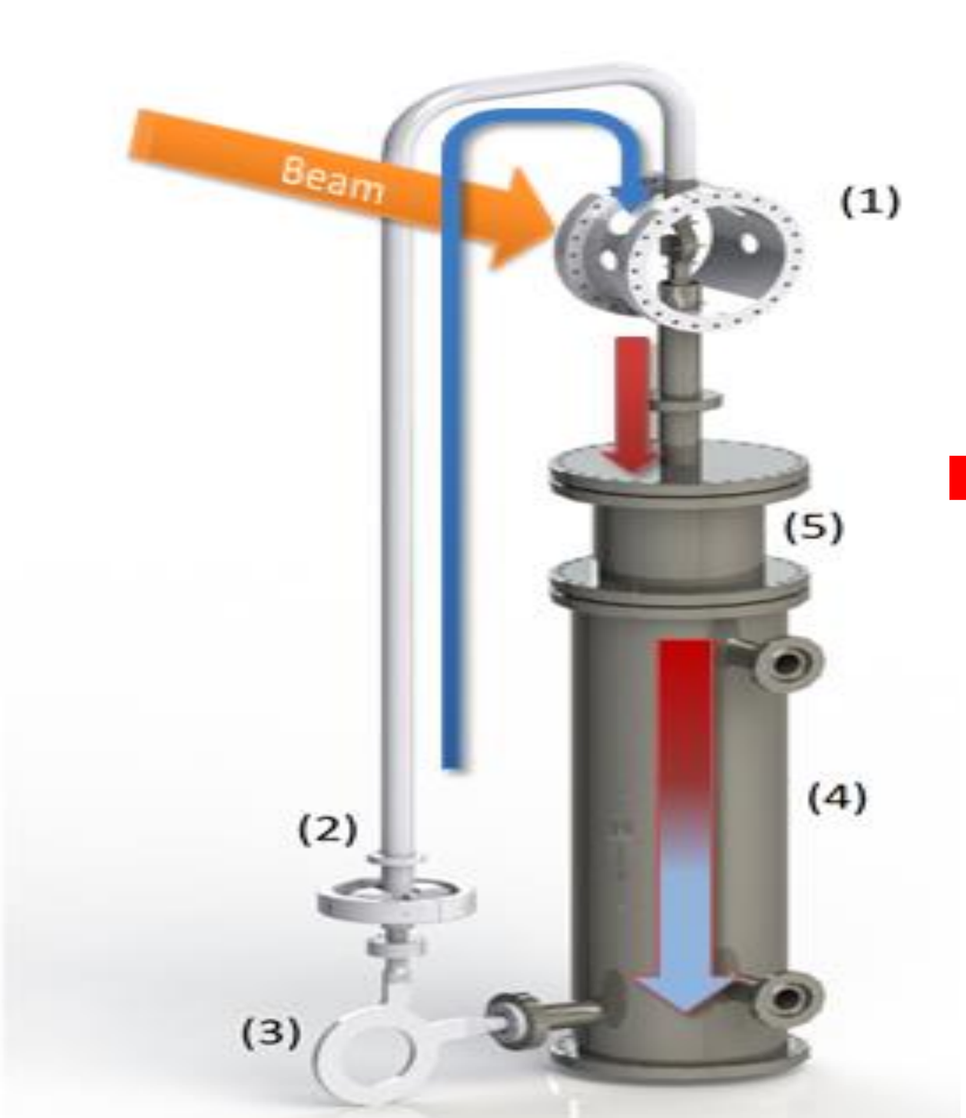
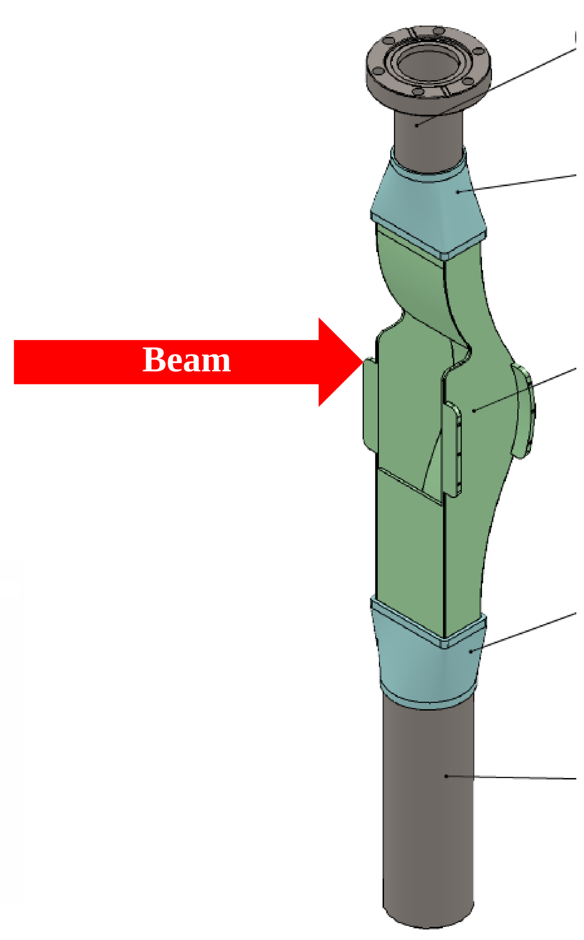
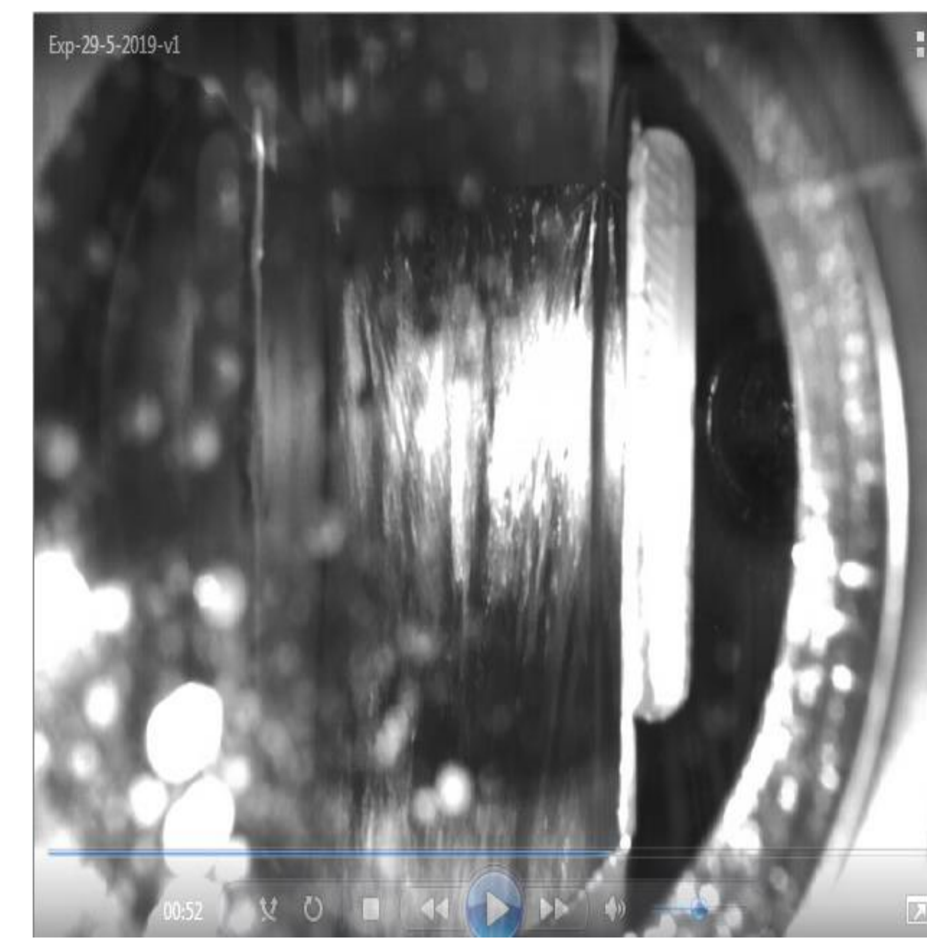
Introduction: The Soreq Applied Research Accelerator Facility (SARAF) is a proton/deuteron RF superconducting linear accelerator. Phase I has already been completed and allows acceleration of 2 mA CW, 4 MeV proton beams and a low duty cycle acceleration of 5 MeV deuterons. Phase II of the project is under way and includes the development of the accelerator to its final specifications: energy of 40MeV proton/deuteron, and a current of up to 5mA. A beam dump will be required for the commissioning stage and daily operation.

The beam dump must be designed to stop a beam with a maximum power of 200 kW. To avoid radiation damage and improve heat transfer, we suggest a design concept of a liquid metal target, based on our prior experience with the liquid lithium target (LiLiT) at SARAF [1]. The suggested liquid metal target is a Gallium Indium (Ga-In) metal alloy with a melting point of ~15ºC, designed to absorb a beam of 200 kW. This liquid metal is used in other applications for dissipating concentrated heat loads such as thermal interfaces for microprocessors, reactors and heat exchangers. The proposed beam dump design is based on a high-velocity windowless gallium-indium jet which absorbs the beam power and generates a stable 5 mm-thick film flowing at a velocity of up to 10 m/sec onto a concave supporting wall. The gallium-indium loop is made of SS316 and includes: a heat exchanger (Ga-In/oil), an electromagnetic pump, a target chamber with a nozzle and various diagnostic elements.



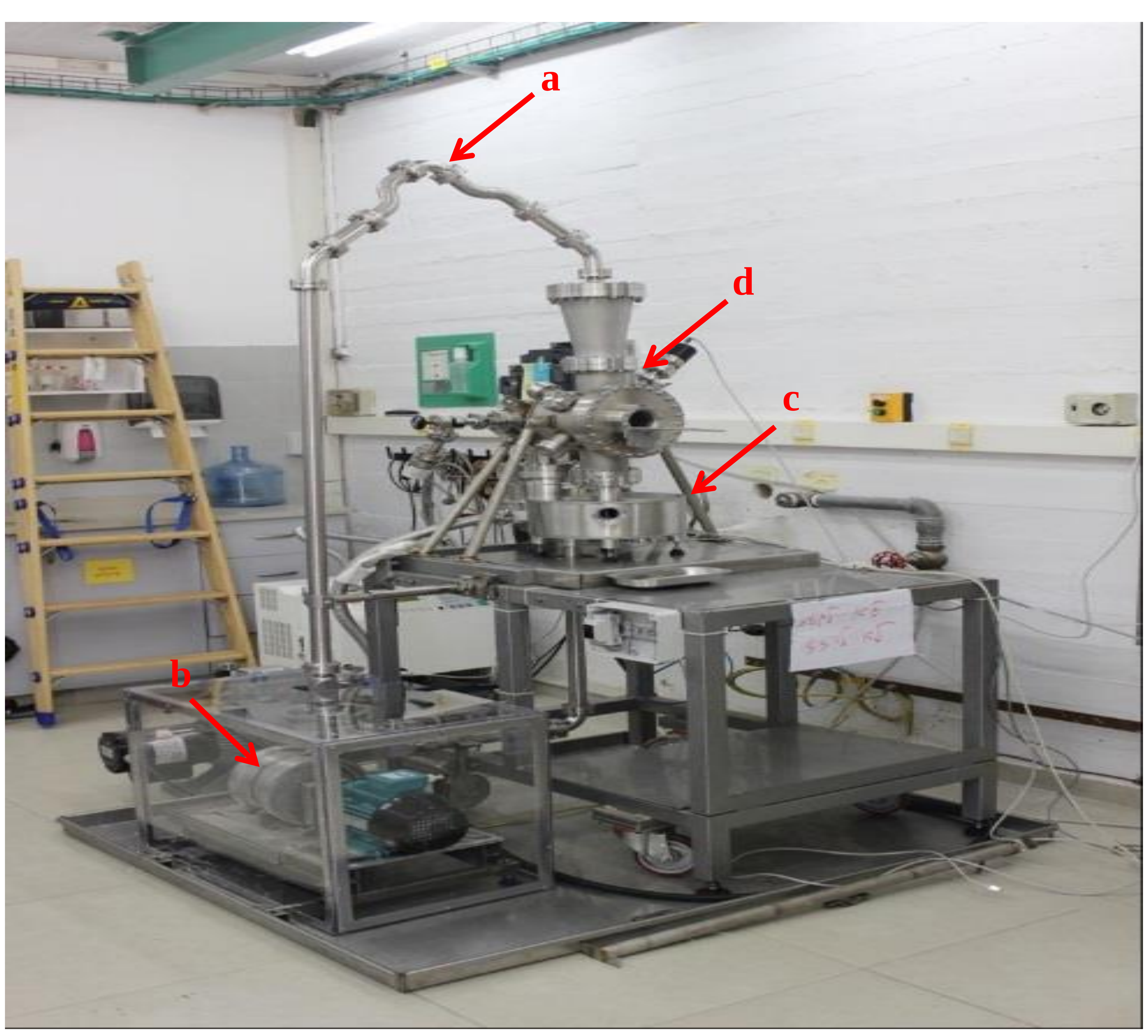


At the nozzle a layer of liquid Ga-In, the compound melting temperature is 15 ºC, forced-flowed at a high velocity onto a concave-curvature thin stainless-steel wall. The target is to be irradiated by a high-intensity proton/deuteron beam impinging directly on the gallium-vacuum windowless interface. The layer width and thickness are determined by the nozzle shape, 50 mm and 5 mm respectively. The nozzle is designed to meet the requirements of SARAF phase II.

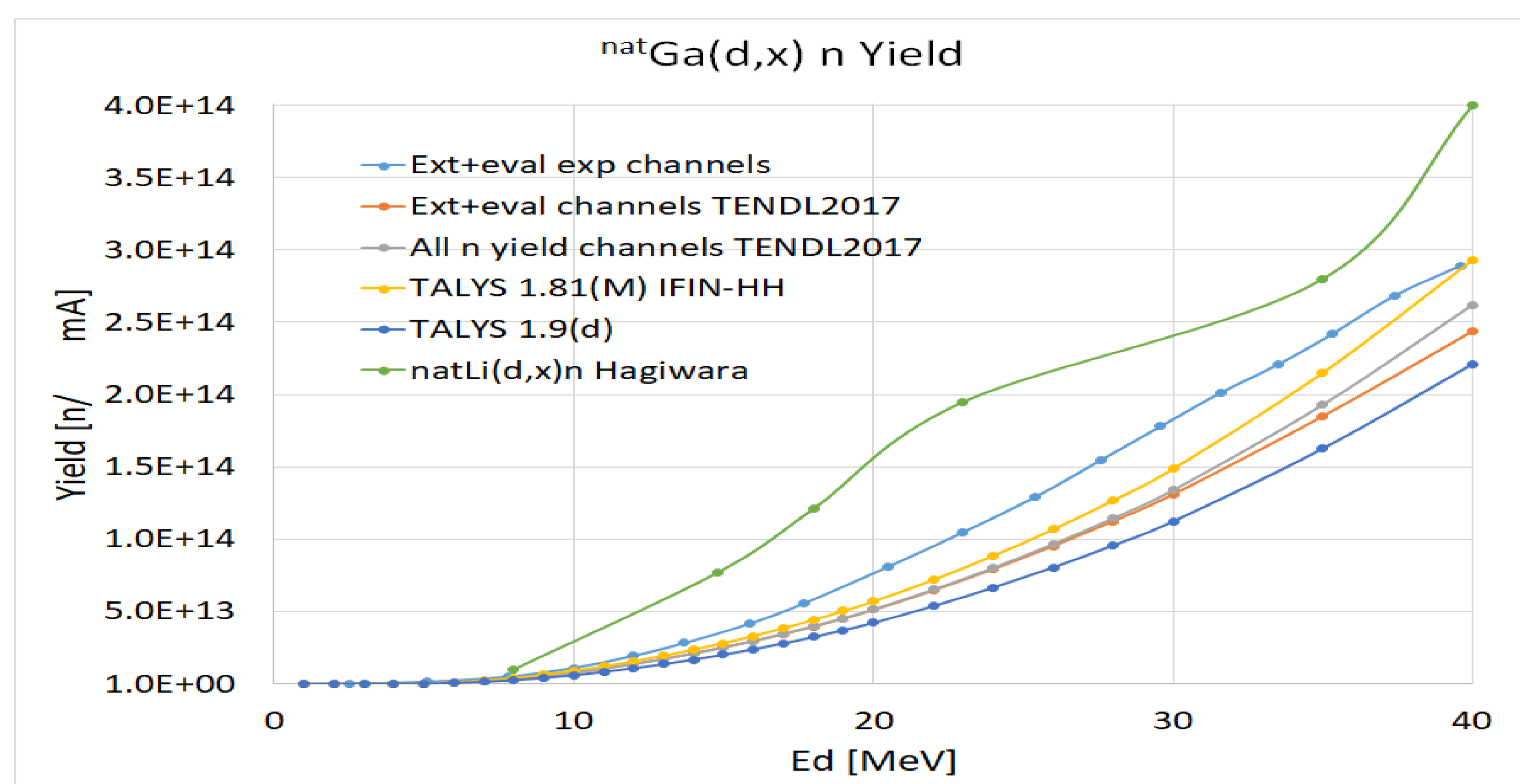


Ga-In flowed in the nozzle

Among the advantages of using Ga-In are good heat transfer, low to none radiation damage, simplicity of adjustments to size and shape of the impacting beam, relatively small residual radioactivity, the low melting temperature of ~15°C and the low chemical and hazard risks, especially compared to lithium.



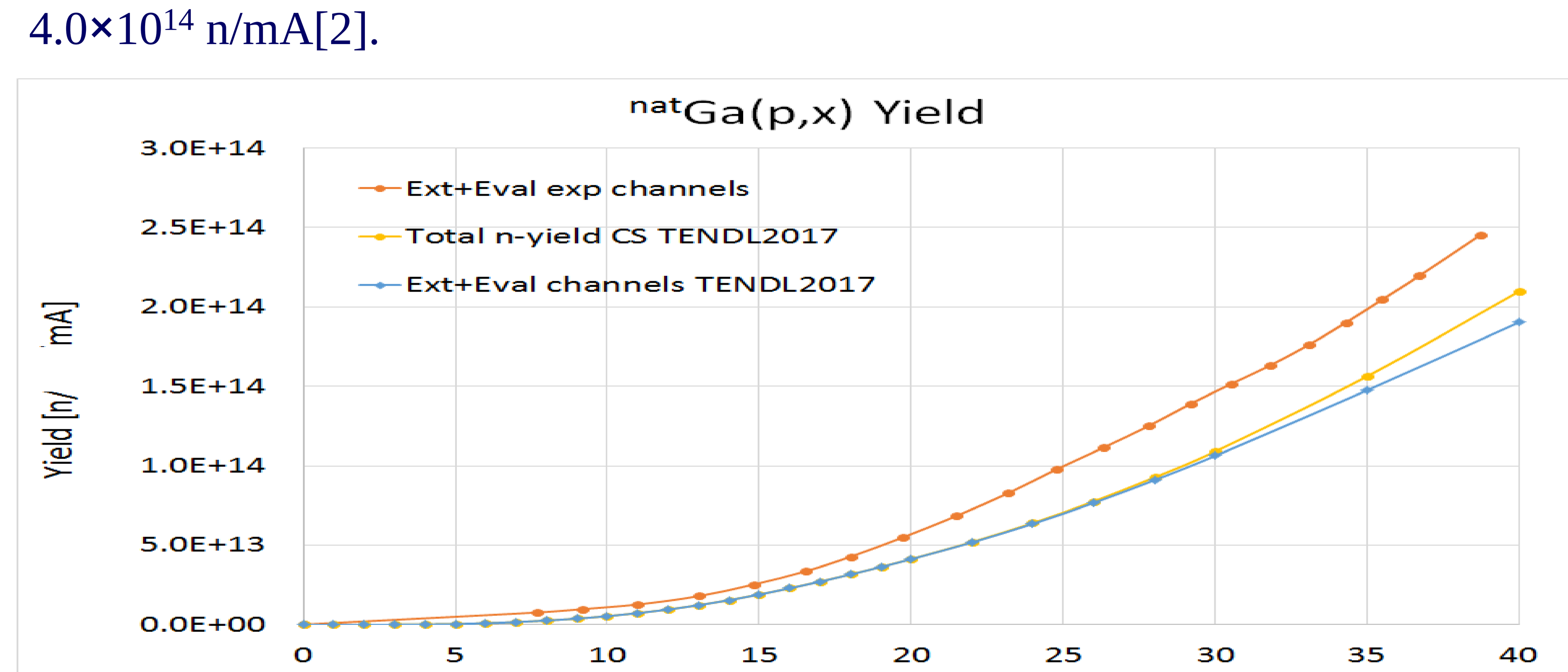
The Ga-In general assembly, consisting of a loop (a) of circulating liquid metal. The liquid Ga-In flow is driven by an electromagnetic (EM) induction pump (b) from the reservoir (c) through the pipes (~3.81 cm in diameter) to the vacuum chamber (d) that hosts the nozzle and finally falling back into the reservoir. The vacuum in the system is maintained around ~10^{-6} mbar. All parts of the system were fabricated from stainless steel 316, and the vacuum gaskets are made of nickel, both compatible with Ga-In alloy.



Total neutron yield from ^{nat}Ga(d,x)n, as a function of deuteron energy. The experimental total neutron yield from ^{nat}Li(d,x)n is also plotted, for comparison [2-6].

The production of neutrons from this target is of great importance for a radiation safety and a possibility of using this beam bump as a powerful neutron source. We have evaluated the neutron flux from natural Gallium (natGa) at the energy and current expected at SARAF phase II (40MeV and 5mA).

The total neutron yield from natGa, when irradiated by protons and deuterons at energies up to 40 MeV are shown in graphs above and below. The evaluation is based on measured cross sections of natGa for most of possible reaction channels, and complemented by estimations of the other relevant channels cross sections via measured trends in neighboring nuclei. The evaluation results were compared to the simulation code TALYS (TENDL2017) and showed a good agreement. The conservative estimation of neutrons yields from natGa are $2.5 \pm 0.4 \times 10^{14}$ n/mA for 40 MeV deuterons and $2.4 \pm 0.3 \times 10^{14}$ n/mA for 40 MeV protons. For a comparison, the experimental yield from 40 MeV deuteron irradiation at natural Lithium is about 4.0×10^{14} n/mA[2].



Total neutron yield from natGa(p,x)n as a function of proton energy [2-6]..

[1] S. Halfon et al. High-power liquid-lithium jet target for neutron production doi: 10.1063/1.4847158
[2] M. Hagiwara et al., “Measurement of Neutron Emission Spectra in Li(d,xn) Reaction with Thick and Thin Targets for 40-MeV Deuterons”, Fus. Sci. Tech. 48, 1320 (2005)
[3] A. J. Koning and D. Rochman, "Modern Nuclear Data Evaluation with the TALYS Code System", Nuclear Data Sheets 113 (2012) 2841, https://tendl.web.psi.ch/tendl_2017/tendl2017.html
[4] A. Hermanne et al., "Proton and deuteron induced reactions on natGa: Experimental and calculated excitation functions", Nucl. Instr. Meth. B359, 145 (2015)
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[6] A. J. Koning et al., “TALYS 1.9 - a Nuclear Reaction Program, User Manual”, December 2017, http://www.talys.eu/home/