TRANSFER OF RIB'S BETWEEN ISOL TARGET AND EXPERIMENT HALLS AT SPIRAL 2

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Abstract

The paper provides a short overview on the main aspects and difficulties of the radioactive and charged particles transfer between a hot cell and the experiment halls. A special emphasis will be given to the developments concerning the beam transfer, the safety issues, the nuclear engineering and the maintenance.

INTRODUCTION

The production of intense radioactive beams with an ISOL process requires a high power target, efficient beam selection and transport, safe operations and reliable equipment [1-5]. The SPIRAL 2 project a so called second generation RIB facility [6] is under construction at GANIL and begins to produce stable beams [7]. RIB' s will be produced by neutron induced fissions obtained from a 40 MeV primary beam (deuterons) and a graphite convertor. Several issues need to be addressed in order to insure the safety rules and ultimately the performances requested by the scientific community. Most of the investigations currently in progress are devoted to the nuclear engineering, the maintenance and the multi-scale integration with the infrastructure. Some technologies and design strategies of the low energy beam transfer line are similar to the ones used for high power targets of neutron sources, high power accelerators and in the nuclear industry [8-11].

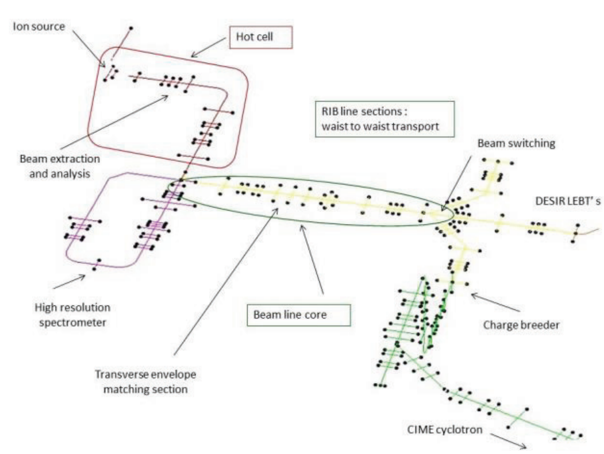

Figure 1: Beam line layout from target and ion source to experiment halls. The core of the beam line connects the hot cell with target and ion source to the secondary beam lines.

BEAM TRANSFER

The extraction and transfer at the exit of the source, see Fig. 1, is not only related to the ion-optics and the collective effects of the desired species but also to the behavior of the contaminants of the beam [12-13]. In the case of Fig. 2, a 1 mA $^{16}O^{1+}$ supporting gas beam is transmitted at 60 keV with the settings of a 50 pμA single charged analyzed ion with mass 108u. Most of the beam intensity is lost after a few meters and the analyzed beam may present a hollow structure thus an emittance increase due to the space charge of the contaminants [14]. The space charge dominated regime during the extraction of the beam, the search of a compromise between beam transmission, rejection of the contaminants (light-ions), and management of the safety are important issues. An efficient vacuum pumping system (550 l/s turbo molecular units), collimator diameters between 14 and 65 mm, assessment of the transmission and trapping coefficients (Movak3D code) provides the nominal conditions for the LEBT extraction at SPIRAL 2. Collimation and vacuum chambers dimensions are consistent with transverse beam envelopes (line acceptance matching beam emittance). Contaminant beams are suppressed and non-ionized particles trapped.

The beam matching, beam loss reduction, settings and failure tolerance of the optical elements are parts of the initial design and tests [15-16].

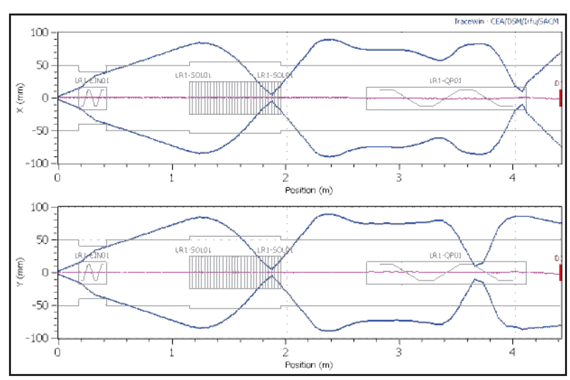

Figure 2: Beam envelopes of the $^{16}O^{1+}$ contaminant with settings for the analyzed beam mass 108u, ± 2.25 mm beam spot, 80 π mm.mrad marginal emittance, 1 mA total beam intensity at 60 keV. 99.9 % of the $^{16}O^{1+}$ beam is lost after a few meters in front of the ion source inside the hot cell (obtained with the Tracewin code).

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SAFETY

SPIRAL 2 is a nuclear facility. Due to the range of the residual radiation level, the facility features a zoning with an inaccessible and a controlled access area. The safety applies to the volatile contaminants trapping (confinement of tritium, explosion risks due to hydrogen), the radiation protection (remote handling, hot cell), and the waste management (cooling water, contamination due to beam mis-steering and transients, corrosion under radiation, direct radiation damage, etc.). Two main principles are applied : first, the exposure to radiation shall be kept as low as reasonably achievable (ALARA) and then, beam losses encountered during machine set-up, beam instabilities, beam scattering on residual gas, etc. have to be minimized. The safety issues i.e. the regulation, standards, quality assurance, procedures, need a pragmatic approach rather than a doctrinal one. The maximum RIB intensity is not only a question of performance; it is also a safety issue in respect of the regulated dose rate in the controlled access area. At SPIRAL 2, the maximal dose rate in the hot cell just in front of the target is 10^8 Gy/Y at full power (200 kW), with 10^{14} fi/s and 10^{11} pps on target. The limits in the controlled area are defined by a standard level of 25 µSv/h and the temporal threshold of 2 mSv/h. Different assumptions (beam losses, time duration/operations, distance of operation, etc.) and incidental scenario have to be taken into account from the initial stage, see example in Table 1, in order to perform a global analysis, to assess the hot spots (Equivalent Dose Rates in Fig. 3), to define the maintenance procedure, safe distance of operation, shielding and time duration.

Table 1: Hypothesis of Beam Losses Based on Feedback from Operations and Beam Optics Predictions

Equipment	Losses (%)	Contamination
Vacuum chamber	0.1 per m	1 mm/surface
Beam stop	100	Bulk
Beam profiler	2	Bulk
Slits	5	Bulk
Quadrupole	0.3	1 mm/surface
Dipole	1	1 mm/surface

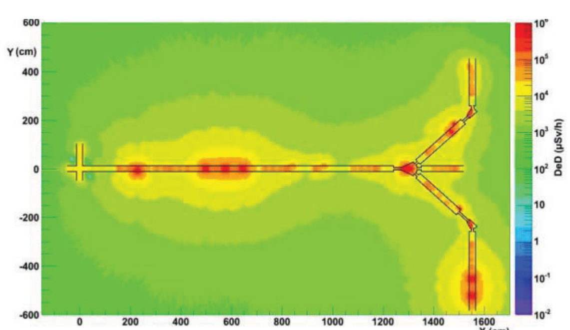

Figure 3: Equivalent dose rate calculation : hot spots on the core beam section in the controlled access area (see Fig. 1). Calculation performed with the MCNPX code and ^{132}Sn beam (total beam activity is 100 GBq).

NUCLEAR ENGINEERING AND MAINTENANCE

The nuclear engineering is a cost driver of the project and is time consuming. It requires new competences. Someone may notice the wide range of the time scale from the beginning of the project to the end of the decommissioning representing several decades. Good design practices and the use of time saving devices reduce installation and removal times and limit the risk of the operation (and promote the RAM: reliability, availability, maintainability). These devices range from the use of adapted mounts so components can be pre-aligned before installation, to the use of 'quick disconnects' for electrical and water connections. Work carried out in the radiation controlled areas ranges from relatively simple and quick maintenance tasks, such as replacing failed vacuum gauge heads, to complex jobs such as replacing a magnet assembly which can involve many different and often complex operations. Different parameters have to be taken into account: radiation dose, time duration of the operation, decay of the radioelements, distance, shielding.

Among the good design practices a segmentation of the beam line with tight modules and the fail safe principle can be noticed. Remote handling is used in the hot cell around the target and the ion source while hands-on maintenance is preferred in the controlled areas. The remote handling and special maintenance operations have to be integrated in the design since the beginning of the project in order to facilitate the unscheduled and preventive maintenances, to reduce the risks and the costs [11, 17]. Despite the existence of some design guideline compromises are unavoidable. For example we noticed that a modular configuration increases statistically the number of failures and thus the EDR during maintenance. Then, the repair and replacement of a component on the beam line have not the same incidence on safety than doing them in a dedicated maintenance room: the EDR for each operation, manpower, tool, procedure, distance, time schedule are major issues. The feedback from operation (here mainly from ISOLDE, TRIUMF, GANIL) is also of primary importance.

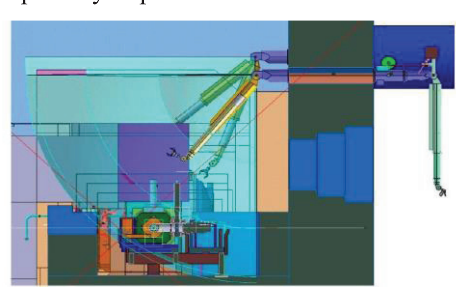

Figure 4: Cross section on the beam line equipement and the interface with the master/slave telemanipulator.

In order to maintain the facility's operational status the alignment of the equipment is an important issue considering the initial offline set-up, survey and matching [18]. In the hot cell, the robot, quick connections, easy access, reliable tools are now parts of the baseline, as well as the now widely used radiation hard magnets [19-22].

MULTI-SCALE INTEGRATION

The integration of the segmented beam line with the infrastructure requires a multi-scale approach in order to be able to deal with the tiny components (fraction of mm) and the large equipment (e.g. the several 100 meters long beam line). Most of the components are being manufactured outside GANIL, however the regulatory requirements are mostly French (CEA/CNRS) or European (for example the Eurocode). It is therefore very important to manage the integration very carefully with sufficient resources on a central location. Some regulatory consultants may be requested during the design and manufacture. Experience and expertise have been developed in the field at CERN and GANIL, see for example [23-26].

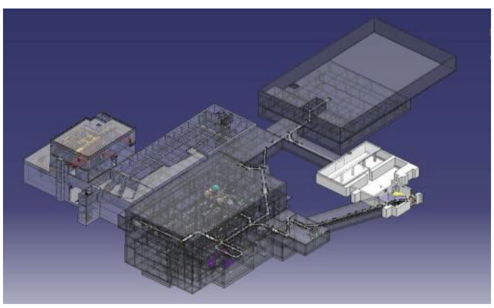

Figure 5: Mock-up of the RIB production building.

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