ISBN: 978-3-95450-207-3 doi:10.18429/JACoW-MEDSI2018-THOAMA03

MECHANICAL ENGINEERING DESIGN AND SIMULATION FOR SPIRAL2 ACCELERATOR @GANIL

C. Barthe-Dejean, F. Lutton, M. Michel, P. Gangnant, C.Michel, P. Lecomte, F. Daudin, C. Stodel, R. Revenko, JL. Vignet, M. Di Giacomo, JF. Leyge, E. Petit, SPIRAL2-GANIL, Caen, France
M.Walter , CC-IN2P3, Lyon, France.

Abstract

The SPIRAL2 project at GANIL is based on a superconducting ion Continuous Wave LINAC with two associated experimental areas named S3 (Super Separator Spectrometer) and NFS (Neutron For Science). This paper reports the main contributions of Mechanical Design Group at GANIL to the project. Mechanical engineers have been highly involved since 2005 from the pre-design of the accelerator and its development until present to finalize the installation. During the development phase, design and numerical simulation were used throughout the complete process: from the ion sources, to the LINAC accelerator, then through beam transport lines to experimental halls equipped with detectors. The entire installation (process, buildings and systems) is integrated in 3D CAD models. The paper focuses on three equipments designed in collaboration with electronics engineers and physicists: the Rebuncher in the Mean Energy Beam Transport line (MEBT); the Instrumentation of Secondary Emission Monitors (SEM profilers), and the Target Stationin S3. SPIRAL2 also has to meet safety requirements, such as seismic hazard, therefore the dynamic simulations performed to demonstrate the mechanical strength in case of earthquake will also be detailed.

INTRODUCTION

The SPIRAL2 radioactive ion beam facility was launched in July 2005, with the participation of French laboratories (CEA, CNRS) and international partners. SPIRAL2 complex is built in two phases: a first one including the accelerator, the Neutron-based research area (NFS) and the Super Separator Spectrometer (S3); and a second one including the low energy RIB experimental hall called DESIR. The SPIRAL2 LINAC takes into account a wide variety of beams detailed in Table 1 to fulfill the physics requests.

Table 1: Beam Specifications [1]

Particles	H+	D+	ions	option
Q/A	1	1/2	1/3	1/6
Max I (mA)	5	5	1	1
Max energy (MeV/A)	33	20	15	8.5
Max beam power (kW)	165	200	45	51

The SPIRAL2 first phase facility is now built; the accelerator installation and connecting tasks are achieved, and the beam commissioning has started with encouraging and promising results. The goal is now to send the first beam for physical experiment in NFS in 2019.

MECHANICAL CAD INTEGRATION

One of the main task of the Mechanical Design Group was to integrate the CAD Models (CATIAv5 files) from the different laboratories participating to the project (Fig.1 and Fig.2). It was decided to use a common PLM (Product Life cycle Management) software: SMARTEAM. This PLM solution allows complex collaborative design development at large scale (Fig.3) . The software license, the installation and the training for all the users in different laboratories were organized jointly by GANIL Mechanical Design Group and IN2P3-CNRS Data Center.

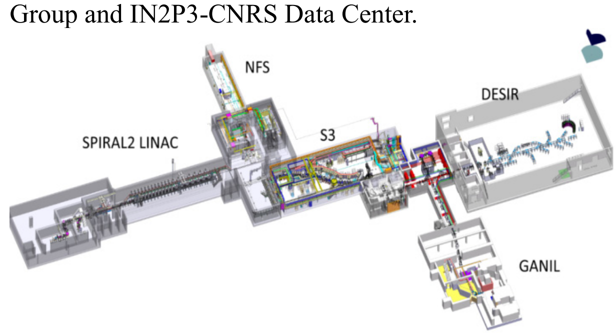

Figure 1: SPIRAL2 CAD complete assembly model.

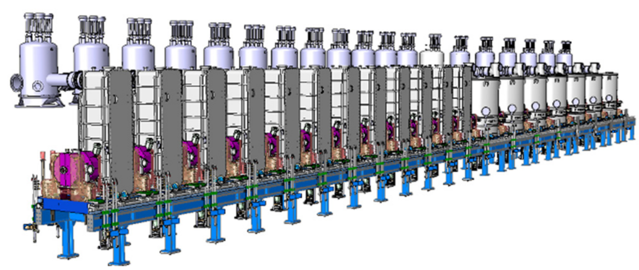

Figure 2: LINAC with its Cryomodules type A and B.

The complete SPIRAL2 CATIA v5 CAD file is 11 Giga-octets. It was assembled by GANIL designers, and is the most important CAD assembly of IN2P3 database. The CAD model of S3 experimental hall itself contains 2700 different sub-models.

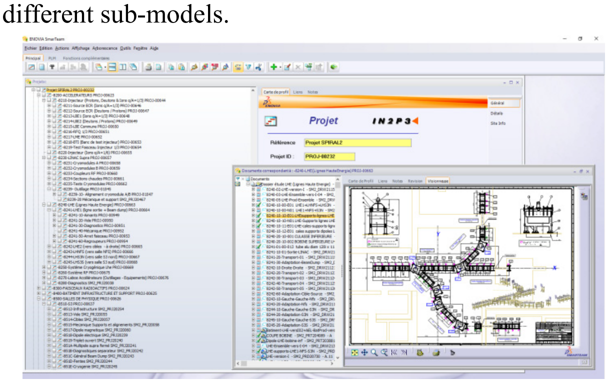

Figure 3: SPIRAL2 Project in Smarteam Data Base.

ISBN: 978-3-95450-207-3 doi:10.18429/JACoW-MEDSI2018-THOAMA03

MEBT REBUNCHER

The Spiral 2 accelerator uses radio-frequency three-gap cavities to prepare high intensity beams before LINAC acceleration. Its function is to ensure and maintain the beam's longitudinal dimension. Those cavities work at 88 MHz [2]. The rebunchers are located in the Mean Energy Beam Transport line. They are made of a copper plated stainless steel vacuum chamber and solid copper parts. The central section is machined from a solid block for more accuracy. The chamber, stems, beam ports and trimmers are water cooled. The stems are cooled by a continuous layer of water flowing inside the tube (Fig. 4).

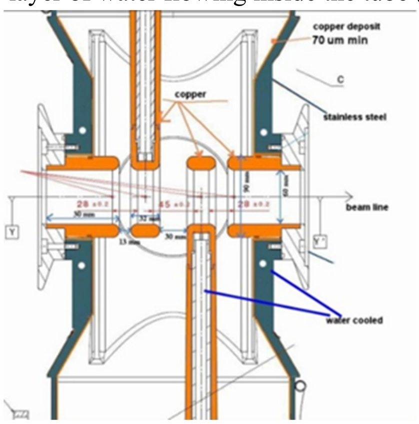

Figure 4 : Rebuncher section [3].

The several heat-transfert simulations (Fig. 5) have allowed to optimize the cooling system in order to ensure a maximum ΔT= 50 °C between all parts [4] : an essential parameter to grants proper functioning of the cavity (the temperature distribution has to be as uniform as possible). A motorized and a manual trimmer panel are added to adjust the distance between the panels and the stem to compensate thermal expansion.

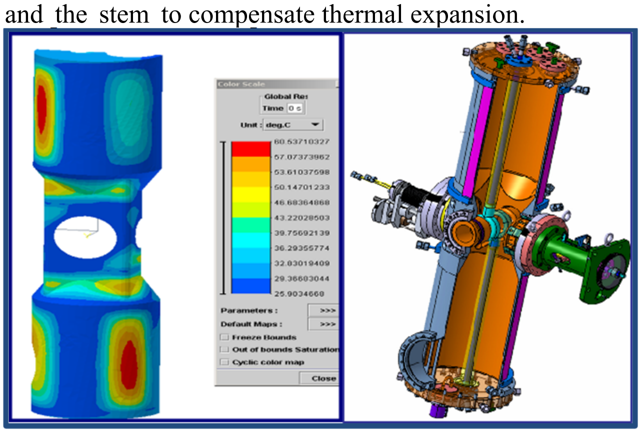

Figure 5: Rebuncher CAD and thermal simulation [4].

S3 TARGET STATION

The design of the stable target station was fully developed by GANIL Mechanical Design Group. The aim is to obtain a stable behaviour of the targets under high primary beams intensities (up to 350 MeV at 10 pμA) [5,6]. In order to withstand this high beam intensity, the 18 solid targets are placed on 6 different sectors which are mounted on a large wheel rotating at high speed (Fig. 6). One of the example of target studied is Uranium on Carbon and Titanium backings [6]. The total thickness is less than 5 μm. The station is designed for several type of targets materials which range from Carbon to Uranium.

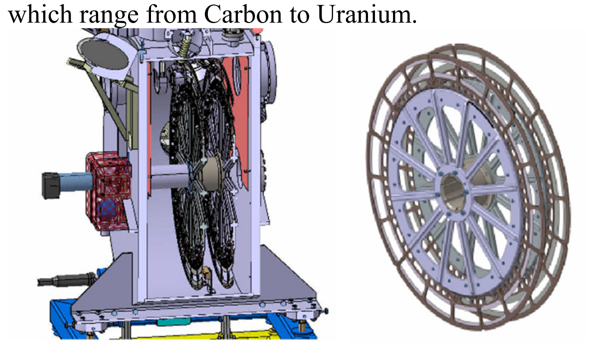

Figure 6: S3 Vacuum chamber assembly with wheel [7].

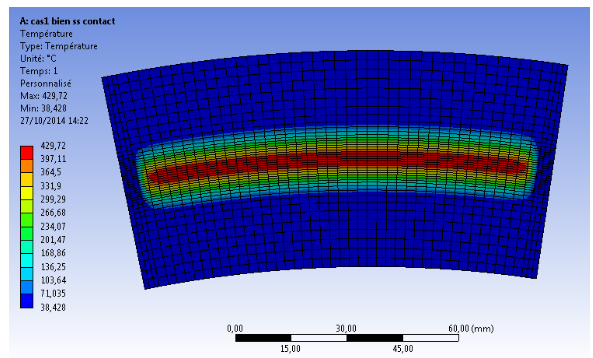

Figure 7: Carbon-Uranium Target thermal simulation [7].

The maximum rotational speed is 3000 rpm (50 Hz) [5,6]. The wheel is made of aluminium to optimize the weight and the shaft is in stainless steel. The shaft is driven by a motor located outside the vacuum chamber: the feedthrough air/vacuum is Ferro-fluidic seal technology based on magnetics sealing for high speed, and specifically designed by the supplier. Dynamic simulations and rotational tests have been realized to determine Eigen frequencies of the system and dynamic behaviour. Different thermo-mechanical simulations have been conducted (Fig. 7) to finally lead to current design with a maximum predicted temperature of 400 °C stabilized after 40 rotations (Fig. 8) [7].

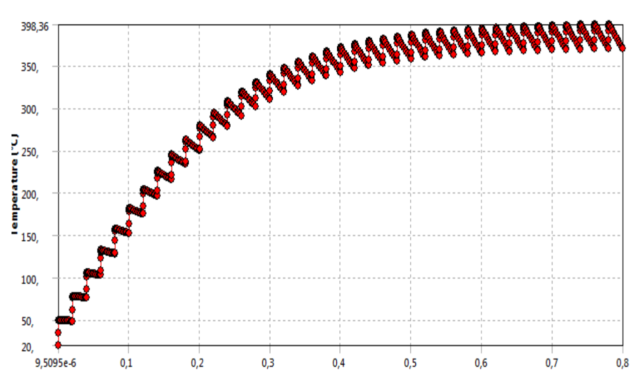

Figure 8: Temperature in the target @3000rpm [7].

ISBN: 978-3-95450-207-3 doi:10.18429/JACoW-MEDSI2018-THOAMA03

SEM PROFILER

The function of the profiler is to characterize the beam position and profile. The profiler is made of tungsten wire Ø20 to Ø150 µm in two orthogonal planes. The beam is passing through the wires and extracts electrons which create an electrical current in the same ratio as the energy transferred to the wire [8]. This type of profiler is used 250 times in all SPIRAL2 beam transport lines (Fig. 9). The actuator has also been developed at GANIL and is used to translate the profiler INSIDE and OUTSIDE the beam with a stroke of 120 mm. The GANIL actuator is now used widely for different accelerators.

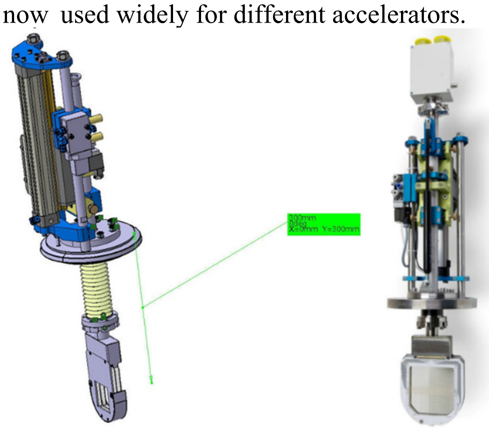

Figure 9 : EMS Profiler.

SEISMIC CALCULATIONS

Safety requirement as specified by A.S.N. (French Nuclear Authority) in terms of seismic hazard have been reinforced. The SPIRAL2 new building is used as containment barrier for radiation protection. In case of earthquake, some equipment has to be designed to ensure that it will not be projected and affect the building. For this reason, all the supporting frame, mechanical support and its anchorage to ground have been calculated to withstand dynamic load corresponding to earthquake S.M.S (Maximum Security Seism). Civil engineering have provided seismic spectral load (Fig. 10) in each building bloc [9]. The simulations have been performed for more than thirty equipments for which weight exceeds 500 kg (example Fig. 11).

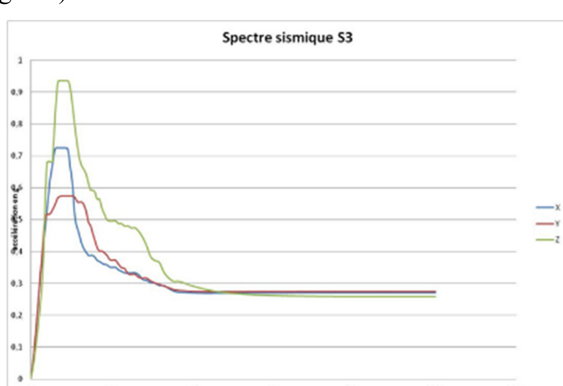

Figure 10: Spectral load for seismic simulation in S3 [9].

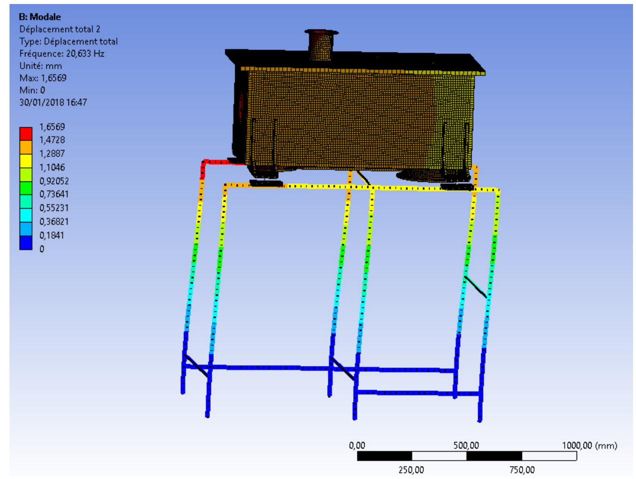

Figure 11: Modal analysis for Detection chamber [10].

The Results are post-treated in terms of Von Misès Stresses (Fig. 12) for all mechanical parts. Each fastener, anchorage and weld is calculated and analysed separately to prove it can meet the Eurocode 3 mechanical design criteria.

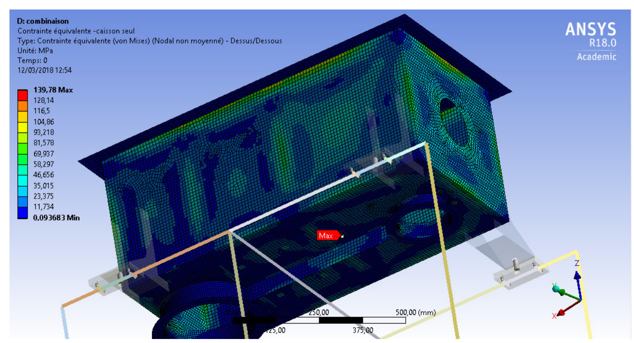

Figure 12: Detection Chamber Von Mises Stresses [10].

A specific computer program based on existing analytical method has been developed on our Finite Element software ANSYS in order to calculate the welds.

For one standard mechanical equipment, the different calculation steps necessary to justify the integrity in case of earthquake last 2 months full-time for an engineer of the group.

CONCLUSION

An international project of a magnitude such as SPIRAL2 has led the designers and engineers to adopt new methods of design and simulation, and has required significant development and upgrading of skills in the mechanical design group in various technical domains including CAD large assembly, heat transfer and dynamic simulation.

ACKNOWLEDGMENT

I would like to thank E. Petit, M. Di Giacomo, F. Lutton, P. Gangnant, M. Michel, C. Michel and P. Lecomte, C. Stodel, R. Revenko (SPIRAL2-GANIL) and M. Walter (CC IN2P3) for their help to collect information presented in this document.

ISBN: 978-3-95450-207-3 doi:10.18429/JACoW-MEDSI2018-THOAMA03

REFERENCES

[1] E. Petit, "Status Report on the SPIRAL2 Facility at GANIL", *Proc. of North American Particle Accelerator Conference (NAPAC'16)*, Chicago, USA, October 9-14, 2016, paper TUA1IO02.

[2] M. Di Giacomo "Design Of The MEBT Rebuncher RS for the SPIRAL2 Driver", *Proc. of LINAC 08,* Victoria, BC, Canada, 2008, paper THP047.

[3] JF Leyge, « Présentation MEBT Rebuncher Test and Results », *GANIL*, 23 janv. 2012.

[4] , M. Michel, F. Pellemoine, JF. Leyge, « Etude Mécanique des regroupeurs de la ligne LME », *STP00027A*, 2008.

[5] C. Stodel, F. Pellemoine, R. Hue, F. Lutton, C. Marry «Targets for S3 at SPIRAL2» *Nuclear Instruments and Methods in Physics Research A*, 2010, vol. 613, pp. 480-485.

[6] Ch. Stodel, J. - F. Libin, C. Marry, F. Lutton, M.- G. Saint-Laurent, B. Bastin, J. Piot, E. Clement, S. Le Moal, V. Morel, P. Gangnant, M. Authier, F. Pellemoine, « High Intensity Targets Stations for S3 », *Journal of Radioanalytical and Nuclear Chemistry,* 2015, Volume 305, Issue 3 pp 761-767 .

[7] M. Michel, F. Lutton, C. Barthe-Dejean, «Tenue thermique cibles stables S3», *S3-NT-8514-I035728V2.0*, 2014.

[8] J-L. Vignet, A. Delannoy, E. Guéroult, P. Gangant, J.C. Foy, S. Cuzon, C. Houarner, M. Blaizot, "The Beam Profile Monitors for SPIRAL 2", in *Proceedings of DIPAC09,* Basel, Switzerland, 2009, paper TUPB07.

[9] « Hypothèses et Méthodologie de Calcul Génie Civil pour SPIRAL2 », *Ref PH1-IES-021-NDC-03540-C.*

[10] C. Barthe-Dejean, F. Lutton, "Calculs de Tenue sismique du Caisson de la Cellule Gazeuse REGLIS", *S3_NT_851E_AT-271894.*