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Executive Summary

This document presents the final report of Task1 of the Work Package 4 - Innovation and Industries. It describes in particular the result of the survey conducted among the GANIL facility industrial users and a business plan proposal for the industrial activities at GANIL facility.

1. INTRODUCTION

The Work Package 4 – Innovation and Industries – has focused on actions towards industrial users and on actions on industrial valorisation and innovation. They are of general interest as: access dedicated for industries for new applications to the existing GANIL accelerators and to the new SPIRAL2 facility, and proposal on involvement of industrial users within GANIL-SPIRAL2 organisation (Task1), general support for industrial valorisation and technology transfer (Task2), and study of the increase of innovation potential of GANIL-SPIRAL2 (Task3).

The Task 1 has dedicated its work on the access for the industrial users to the beam proposed by GANIL-SPIRAL2 facility. When the project was defined, the pilot access for beam time was supposed to be dedicated mainly to SPIRAL2 facility, for which some new industrial tests had to be developed. The starting schedule of this facility was somewhat delayed, thus beam access to industries could be proposed only on GANIL facility, to new companies, in order to attract them to come regularly in the future.

Nevertheless, the study conducted for the proposal on involvement of industrial users has concerned both facilities GANIL-cyclotrons and SPIRAL2.

The business plan for the industrial application activity at GANIL has been, on the other hand, studied and established for the existing GANIL facility, for the main two industrial activities: electronic components irradiations, and microporous/nanoporous membrane development and production. For the SPIRAL2 part, one has to wait for a more routine operation to calculate operation costs in order to propose adequate economic model and business plan.

2. STUDY WITH INDUSTRIAL USERS

2.1. INDUSTRIAL APPLICATIONS STATISTICS OVER 2010-2020 PERIOD

A statistical study has been performed on the beam time scheduled in the last ten years of GANIL period.

2.1.1. ELECTRONIC COMPONENT ACTIVITY

For the electronic component irradiation, the beam request by industrial companies which come to GANIL is exclusively focused on heavy ion beams, with high LET (Lineic Energy Transfer) and high ranges in silicon, corresponding to the Xenon and Lead beam at the highest possible energies. These beam characteristics are unique among the European facilities, the other existing similar facilities are located mostly in North America and some in Asia.

The results among 15 industrial users are the following:

- 5 of them have been using GANIL beam every year since 2010 with a beam time scheduled between 16 to 40 hours. They correspond to large national and international groups.
- 3 more have been using GANIL beam every year since 2017 with a beam time scheduled between 16 to 32 hours. They are both intermediate size companies and companies which usually used facilities in North America

- 1 used to come every year until 2015, and has decided to proceed through the interdisciplinary physics program advisory committee coordinated by CIMAP laboratory. They work mainly on R&D projects.
- 6 come sporadically with beam time request/schedule of 8 to 16 hours. They are SMEs.

2.1.2. TRACK-ETCHED MEMBRANE ACTIVITY

For the track-etched membrane irradiation, the beam request by industrial companies which come to GANIL is focused on heavy ions from Krypton beams up to Lead beams and rather high energies, as the film thicknesses may vary in a large range. One of the specificities of GANIL in this domain concerns the high energy very heavy ions (Lead beams) which allow to produce thick membranes, not available in most of the European facilities.

The results among 5 industrial users are the following:

- No company has been using GANIL beam regularly since 2010.
- Two companies used to come between 2010 and 2015, for their own development, using 16 beam hours for each campaign. They are using now another European facility for their industrial production, where beam is more available.
- Two companies have been using GANIL beam since 2015 with 100 to 120 beam hours scheduled for each experiment, but could not come from 2018 due to the non-availability of GANIL beam since then for these activities.
- One company has been using GANIL beam since 2018, with a scheduling of 24 hours each year (not including beamtime cancellation due to accelerator's failure or COVID in 2020).

2.2.SURVEY FOR INDUSTRIAL USERS

A survey was launched in 2020, in order to evaluate the requirements of industrial users in terms of beam type and beam time for the next six years. The final aim of this survey is to propose some new organisation to the next directorate mandate (from 2022), regarding beam scheduling and participation to GANIL organisation, in order to increase the offer from GANIL part to irradiation needs from the industrial side. One other scope was also to identify new needs for neutron beams produced by the SPIRAL2 facility.

2.2.1. PRESENTATION OF THE INDUSTRIAL PANEL FOR THE SURVEY

The panel concerned by the survey was composed of the industrial contacts mailing list of the person in charge of industrial applications.

This mailing list is composed of 85 companies for electronic component irradiation tests, and 10 companies for track-etched membranes irradiation.

2.2.2. RESULTS OF THE SURVEY

For the electronic component irradiation activity, 10 companies answered the survey (on 85). They are mainly large international groups, among which one American company and one Chinese company (with the highest requirement/year). These last two companies have not used yet GANIL beams.

For the track-etched membrane irradiation, 3 companies (on 10) answered, among which a Chinese company with a high request.

The results in terms of beam-time request are summarised in the following table:

Beam Time Request (hours/year)	GANIL beam 2022-2024	GANIL beam 2025-2027	SPIRAL 2 neutron beams
Electronic components	270	320	YES, to be identified more precisely
Track-etched membranes	350	500	Not concerned

We can draw three main information from this table:

- for electronic component irradiation, the request will slightly increase in the future
- for track-etched membrane irradiation, an important increase is foreseen in the future (2025-2027), due to important perspective with the development of new applications with track-etched membranes (see Report Deliverable D4.3)
- for the use of neutron beams at SPIRAL2 facility, the needs are not yet clearly identified.

2.3. PROPOSAL FOR FUTURE GANIL ORGANISATION REGARDING INDUSTRIAL APPLICATIONS

Several discussions took place with some industrial users, all along these last years, mainly on the critical lack of beam time. It is important to underline at this stage that the global request for irradiations of electronic components is much larger that the available beam time, both at European level and international level. The situation is somewhat less critical for the membrane production, even if for the R&D activities, in particular regarding the use of new thick materials, very few facilities can meet the requirements.

The global GANIL answer for industrial beam requests was around 80-90% up to 2017. From 2018 to 2021, the "scheduling rate" i.e scheduled beam time compared to requested beam time decreased from 60% down to 53% for 2021. One proposal to find solutions to increase again this "scheduling rate" could be that a representative of the industrial applications participate to the GANIL User Executive Committee (see WP2 for GUEC description and activities), in order to elaborate general beam operation schedule by considering this request; it could be submitted for consideration to the next GANIL directorate. As presented in §2.2, the 40% missing beam time would correspond in total to a maximum of 240 hours, which would mean 10 full days more operation per year, to be distributed among several operation runs.

Another proposal would be to include again the "industrial" indicators in the general GANIL indicators (beam request, beam allocation). They were removed from these indicators from 2017. An increasing request from research ministry and European institutions for more industrial applications and collaborations with the large-scale research facilities could motivate this proposal.

The last point to be underlined is that GANIL is a partner of the recently funded H2020 project RADNEXT, whose one of the tasks is to optimise at a European level, the attribution of beam time in the various facilities according to the requirements. The aim is to better identify the specificities of each facility, and to increase the use for industrial applications, in the facilities which might have more beam time available, if their beam characteristics are in adequacy with the industrial requirements. That would allow to better satisfy the global request at a European level.

3. ECONOMIC MODELS AND BUSINESS PLANS FOR INDUSTRIAL ACTIVITIES AT GANIL

The proposal for a new economic model and several possible business plans has been concentrated on the track-etched membrane irradiation. For the electronic component irradiation activity, the presentation in this report is limited to the estimated cost of irradiation and the description of the present economic model.

3.1. BUSINESS MODELS AND BUSINESS PLAN FOR THE TRACK-ETCHED MEMBRANE ACTIVITY

GANIL has been involved in the track-etched membrane (TEM) irradiation almost since its creation in the 1980s.

The demand for this technology has increased substantially, and this field has been identified as one of the potential innovations for GANIL future activities; a detailed study of this field and a preliminary identification of the market are presented in deliverable D4.3 "Study of the innovation potential increase".

The business models and business plans presented in this report rely on this detailed study. The global market analysis showed many current and potential future applications of the TEM technology in various domains, e.g. healthcare, energy, environment, and electronics, just to name a few. Currently none of these domains expresses a need for a high volume of TEMs that GANIL can deliver. Nevertheless, some new applications with TEM are emerging, and which need the use of new (and thicker) materials. Thus, GANIL added values for this kind of new developments have been identified:

- **Large variety of available ions (light to heavy ions)**
- **Wide energy range (up to high energy 29 MeV/A for Pb beams)**
- **Much wider range of material types and thicknesses than in other similar facilities**
- **High beam stability**
- **Online and precise beam monitoring**

In order to maintain GANIL's sustainability and progressive development of its activity around ion track-etched technology, three possible business models have been studied and are presented.

3.1.1. ESTIMATED COST OF TRACK-ETCHED MEMBRANE PRODUCTION IN GANIL

The technical description of the equipment used for track-etched membrane irradiation is presented in deliverable D4.3.

The fixed costs of TEMs production at GANIL's facility using different beamlines calculated for 8 hours and 1 hour (of continuous beam operation have been evaluated according to IDEAAL/WP3 modelling. This modelling needs to be completed by the introduction of depreciation rates, but in the case of the whole equipment used for this activity, the depreciation rate will be rather low as the last equipment was built in 1987 and is fully amortized now. Staff relates to all people working in GANIL's facility during the beam irradiation experiment.

Type of the beamline	**CSS1 (thin film)**	**CSS1 CSS2 (thick film)**	**CIME (thin film)**
GANIL's Real Cost of Operation per Single Unit (1 UT = 8 hours)			
Price with staff	43 000 €	56 000 €	36 000 €
Price without staff	14 000 €	17 000 €	12 000 €
GANIL's Real Cost of Operation per One Hour			

Price with staff	5 375 €	7 000 €	4 500 €
Price without staff	1 750 €	2 125 €	1 500 €

The effective price for TEM irradiation strictly depends on the experiment and is beamline-dependent. The detailed irradiation cost varies according to the beam energy, beam intensity and expected pore density so it should be calculated individually for a certain type of polymer (e.g. thin or thick film) and its final characteristic (e.g. low/high pore density), and the standard way to calculate it is to evaluate the beam hour cost. The table above represents the full cost of GANIL per beam hour.

One has to consider also the "market" price among the European facilities able to produce TEM irradiation and the proposed GANIL price must fit this market price as well.

For the track-etched membrane irradiation, an additional fixed price is added, independently of the number of hours for production. It is the time necessary for the tuning of the beam line and the pore density calibration (which needs some chemical treatment), and corresponds to an eight-hour fixed package. Usually, only one company is scheduled for a membrane campaign; in case they would be two using exactly the same beam and same order of pore density, this fixed price would be divided by two.

The chosen price will be the price without staff, as GANIL permanent staff is paid by the GANIL funding agencies CEA and CNRS.

3.1.2. Current Business Model of GANIL for TEM

Until now, the GANIL's revenue from the TEM activity comes exclusively from selling the beamtime to external users (i.e. irradiated raw polymeric material without any chemical post-treatment). Access to the GANIL's beam is granted and regulated via a beam sale contract after booking the beamtime 6 months in advance. Using such a Business Model (BM0) the GANIL's revenue depends directly on 2 factors:

- the number of beamtime hours/year available for customers
- the number of beamtime hours sold for a certain price

The summary of GANIL's revenue coming from the TEM activity between 2014 and 2018 for the current BM0 is presented in table below.

BM0 - GANIL's Revenue from Selling the Beamtime to External Users for TEM production (2014 – 2018)

Year	2014	2015	2016	2017	2018
Number of beamtime hours sold	32	106	117	100	24
Price per beamtime (euro/hour)	875	880	890	900	910
Total Annual Revenue (euro/year)	28 000	93 280	104 130	90 000	21 840
Mean Annual Revenue (euro/year)	**67 450**				

The price of the beamtime available for customers was progressively increasing (starting from 875 euro/hour in 2014 up to 910 euro/hour in 2018). The minimum annual revenue was 21 840 euro/year (in 2018) and the maximum 104 000 euro/year (in 2016). The average revenue of the GANIL facility for the given period of time was 67 450 euro/year. In 2019 and 2020 the price for one hour of beam irradiation for TEM was fixed to be 920 euro/hour and

930 euro/hour, respectively, but there was no TEM campaign scheduled. It is worth noticing here that the total number of beamline hours sold to external users also varies significantly making the annual GANIL's revenue highly unstable.

3.1.3. Business Model 1: Increase of Commercial Visibility of GANIL Towards the Production of Track-Etched Membranes

The first Business Model (BM1) proposed corresponds directly to the current one, however, an extensive promotion of the TEM activity in GANIL is assumed. This BM1 is predicted to result in a higher number of beamtime hours sold to external customers due to growing demand for the beamtime in GANIL and to a higher beam time available for this activity. Access to the beam is regulated via a beam sale contract, like in BM0. Promotion activity can be done as a part-time work of one person (0,1 m.y) who is directly linked with the TEM activity and currently works in GANIL, if the demand is lower than available time (did not occur these last years). The simple simulation of expected revenue within the next 5 years (between 2021 and 2025) is presented in the following table, for an increased price policy of 1000 euro/hour.

Predicted GANIL's Revenue for the Business Model 1 between 2021 and 2025

Year	**2021**	**2022**	**2023**	**2024**	**2025**
Number of beamtime hours	24	50	150	200	300
Proposed beamtime price (euro/hour)			1 000		
Annual Revenue (euro/year)	24 000	50 000	150 000	200 000	300 000
Mean Annual Revenue (euro/year)			**144 800**		

Revenue: 24 000 - 300 000 euro/year (between 2021 and 2025)
The beam cost is not taken into account, as it is included in the annual GANIL expenses, whatever be the use of the beam.

As the visibility of GANIL increases it can be expected that the customer demand for the beamtime also goes up. In the past, GANIL sold at least 24 hours with a maximum of 117 hours a year of the beamtime to external users (between 2014 and 2018). The BM1 aims to increase this number with a maximum number of beamtime hours available in 2025 predicted to be 300 (3 times more than in 2017) and which corresponds to demand expected for the next 3 years, even if rather conservative figure when compared to the result of survey. However, the final revenue of BM1 is strictly dependent on the percentage of annual beamtime the GANIL directorate allocates to this activity.

Pros:

- ✓ No investment risk
- ✓ Possible increase of the current price of the beamtime to approach/overpass the production cost
- ✓ Constant promotion of GANIL's facility may open new doors for potential collaborations allowing to switch in the future to the next BM2 or BM3 proposed
- ✓ The potential high-volume market or niche application can be probed by having an open dialog with prospective new beam users.

Cons:

- The GANIL's revenue remains unstable and dependants on the GANIL directorate politics
- The BM1 does not increase the GANIL's 'know-how' nor the potential future value
- Lack of initial investment limits possibilities for extensive further market exploration
- The new beam price policy of using increased cost (1 000 euro/hour estimated in 2021) does not give the full production-cost recovery

Final remarks: This model is not effective in case of a low number of beam hours sold to external users which is directly linked to the total number of beamtime hours/year allocated for the TEM activity. On the other hand, the BM1 can be profitable if number of allocated beamtime hours per year remains constant or even increases. In BM1 GANIL's promotion activity intends to increase number of external partners and hence the total TEM beamtime usage.

3.1.4. Business Model 2: Contract(s) with an Existing Company

The second Business Model (BM2) is similar to the first one but a possibility of a long-term contract with an industrial partner is assumed. The competitive advantage of GANIL may be of a high attractiveness for the companies who are interested in expanding or developing their current TEM product line. The commercial TEM producers have significantly higher level of expertise required for the full two-step TEM production process (e.g. beam irradiation + chemical etching) as compared to GANIL together with the global market knowledge. In BM0 and BM1 short-term access to the GANIL's beam is regulated via a beam sale contract, but in BM2 multi-annual industrial contract is expected to be signed. On average, the duration of such contract is minimum of 3 years with a constant number of beamtime hours granted each year to a partnership company. Past GANIL's experience shows that companies pay for at least 24 hours of the beamtime for a typical R&D activity with a maximum of 96 - 120 hours (4-5 days) of irradiation dedicated to commercial TEM production (e.g. 70-80 of polymeric rolls), this maximum time being imposed by GANIL. In BM2 two price models are being proposed: the new price (1 000 euro/hour in 2021) and an increased one (1 250 euro/hour).

Predicted GANIL's Revenue from the Business Model 2 between 2021 and 2025

Year		**2021**	**2022**	**2023**	**2024**	**2025**
Predicted future number of beamtime hours		24	50	150	200	300
Minimum Revenue	**Min. number of beam hours sold**			24		
	Beam price range (euro/hour)			1 000 - 1 250		
	Annual Revenue (euro/year)			**24 000 - 30 000**		
Maximum Revenue	**Max. number of beam hours sold**			300		
	Beam price range (euro/hour)			1 000 - 1 250		
	Annual Revenue (euro/year)			**300 000 – 375 000**		

Revenue: 24 000 – 375 000 euro/year

Assumptions: minimum revenue assumes one industrial contract with commercial user signed for at least 24 hours of the beamtime usage; maximum expected revenue does not exceed the maximum number of beamtime hours predicted to be available in 2025; the cost is not taken into account, as before, as it is included in the annual GANIL expenses, whatever be the use of the beam.

Pros:

- ✓ No investment risk
- ✓ Minimum stable income per year regulated by the industrial contract
- ✓ Possible increase in the current price of the beamtime to overpass the production cost.

Cons:

- The revenue depends on the number of industrial partners and the beamtime usage
- Lack of industrial contract may result in zero net income for GANIL
- The BM2 does not increase GANIL's 'know-how' and potential future value while limiting access to the knowledge related to global market/end-user needs
- The intellectual property (IP) belongs to the industrial user, which limits GANIL's access to TEM technology and possible future market
- In case of limited access to the GANIL's beam (e.g. due to annual shut down or technical problem) there is a possible risk of the partnership company using another facility (the exclusion applies to the situation when GANIL is the only place around the world able produce certain type of TEM)
- The price policy does not bring additional revenue back to GANIL on top of the real cost.

Final remarks: An industrial partnership of GANIL with a company can ensure a stable number of beam hours every year. However, from the author's point of view, the real price of GANIL (i.e. 1 500 euro/hour as for the CIME beamline) and the current cost (930 euro/hour) appears fairly high and may not attract any long-term industrial partners. In any other case, the long-term contract should take into account the past minimum revenue (21 840 euro/year for 24 hours of beam irradiation in 2018) and the maximum revenue (104 000 euro/year for 117 hours of beamtime in 2016) with an average of 67 450 euro per year (as seen between 2014 and 2018). Keeping that in mind, GANIL should always aim at signing an industrial partnership allowing to ensure an annual revenue that is no lower than the average revenue from the past 5 years (i.e. 67 450 euro/year). Another possible solution helping to maximize the income is a variable pricing policy depending on the number of hours granted per one industrial contract, as presented below:

Proposed Alternative Beamtime Price Policy for the BM2 in the case of an industrial partnership

Number of beamtime hours	Price per One Hour	Maximum Annual Revenue
50 hours and less	1 250 euro/hour	62 500 euro/year
50 hours up to 100 hours	1 150 euro/hour	115 000 euro/year
150 hours up to 300 hours	1 000 euro/hour	300 000 euro/year

Companies & Industrial Partners for BM1 & BM2

In both Business Models proposed (BM1 & BM2) in the previous sections, the GANIL's revenue relies directly on the beamtime dedicated for irradiation of raw polymeric films. An increased promotion of GANIL's facility (BM1) or industrial partnership (BM2) with an existing company which allows to meet the main objective (i.e. an increase of GANIL's annual revenue) of both models can be done by contacting potential companies which could be interested in the future either by BM1 or BM2.

3.1.5. Business Model 3: R&D Project + Start-up Company

The last Business Model (BM3) is a sum of BM1 and BM2 with a possibility of start-up company creation based on the R&D program developed around the TEMs in GANIL associated to a chemistry team. To enter the global market as a TEM producer, GANIL/chemistry laboratory must increase its technical expertise (i.e. two-step production capability including beam irradiation, chemical etching together with material characterization) and gain market knowledge (e.g. new market, customer needs/preferences). The BM3 allows conducting market studies in parallel with the R&D program to address many potential TEM applications. This approach may open new doors for the creation/detection of a high-volume market or niche market with moderate- or high-cost innovative technology.

Up-to-date, GANIL used to sell exclusively the beamtime to external users for irradiation of raw polymeric films with no access to chemical etching, material storage nor any flexibility in terms of the production size (i.e. only large-scale beam irradiation is possible in GANIL). To run the full two-step TEM production business GANIL must combine its beam irradiation expertise with post-irradiation polymeric film treatment/characterization (by a chemistry laboratory) and TEM business consultant. GANIL/chemistry laboratory should start its TEM activity by building a small-scale production capability allowing it to find the future niche or large-scale TEM market.

To do so, a two-step BM3 can be proposed:

1. First step - identification of a potential application that may generate tomorrow's high-volume market via conducted R&D research.
2. Second step - classical approach with BM for a company addressing a local/global market.

To fulfil the first step of BM3, a common activity between an R&D team based in a chemistry laboratory and a startup based in Caen can be used to:

- Build a research program around R&D activity addressing the local need with initial investment towards small size production capacity (e.g. small device for medium energy beam is needed to produce TEM samples no bigger than the A4 format,). The R&D activity followed by startup creation will allow to address many potential applications by testing different kinds of TEMs. It is suggested that the first possible application of TEMs may focus on activities that are of high interest in the Normandy region (e.g. human/animal healthcare, agriculture, food industry or biogas). This may simplify and give some advantage above other projects to obtain funding while meeting the regional needs.
- In parallel to the R&D activity, the start-up team can also increase GANIL's visibility via constant promotion (BM1) or industrial partnership with companies that need the TEMs to run their business (BM2). In addition to that, small sales of the TEM samples can be organized to probe the market and adapt to potential customer needs.

The second step of BM3 assumes that a high volume/high-cost market was detected in step one to explore the current large-scale production capability of GANIL (e.g. ready to use roll system set-up).

Predicted GANIL's Revenue from Business Model 3 between 2021 and 2026

Year	2021	2022	2023	2024	2025	2026
Business Plan	**Year 0**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Beamtime Sales Revenue (BM1&BM2)	24 000 - 375 000 euro/year					
50% of R&D project/funding (euro/year)	0	100 000	150 000	200 000	0	0
50% of start-up income (euro/year)	0	0	0	100 000	150 000	200 000

Cost: Investment (76 570 euro) + 2 x 1 MY salary (75 000 – 145 000 euro/year) + Annual Operation Cost (20 000 – 25 000 euro/year)

Revenue: 24 000 - 375 000 euro/year (BM1&BM2) + 50 % of External Funding (max. 100 - 200 euro/year for year 1 - 3) + Internal money from GANIL/chemistry laboratory (year 1) + 50 % start-up TEM sample sale (year 4 and 5)

(Assumptions: Investment corresponds to upfront chemistry laboratory and office equipment Cost: 76 570 euro; Annual Operation Cost: Business Consulting 5 000 euro/year + Lab Operation Cost 15 000 - 20 000 euro/year; note that the cost may differ depending on the year, as described in details in the next section)

Pros:

- ✓ More time to gain expertise in the full production process of commercialized TEMs
- ✓ Possibility to probe the market towards detection of niche, innovative TEM application or high-cost/high-volume market
- ✓ GANIL/chemistry laboratory may own the IP on novel TEM applications
- ✓ Increase of the 'know-how' value of GANIL
- ✓ Potential increase of GANIL's global visibility due to multi-channel communication of TEM activity via internet website or social media.

Cons:

- High investment risk
- Possibility of unstable or zero net income in case the start-up company is not profitable
- The success of the startup being dependable on personal motivation and the expertise level of people recruited by GANIL/chemistry laboratory to run the R&D program and TEM business.

Final remarks/hints: Future development of the TEM technology can be connected to the creation of membranes for a particular use (e.g. functional groups, adsorption of proteins). GANIL/Chemistry laboratory may enter the current global market by producing complementary TEMs with quality/price balance or by using its competitive advantage (e.g. different types of polymer/thicker polymer as compared to commercial PC, PET, and PI). The second way to breakthrough is by creating a new market and in this case, GANIL/Chemistry laboratory must have unique technology for a modern type of TE membrane (i.e. novel TEM application for new market opening). The specific application may require some additional investment.

3.1.6. Business Plan for the Business Model 3

In relation to the proposed BM3, described in the previous section, a following 5-year Business Plan (BP) can be suggested:

Year 0:

- Preparation of Regional Normandy Funding application with a one-page R&D program description (see section 3.1.7).

Year 1:

- If regional funding from Year 0 in place the next steps are:
  - Building the chemical facility adapted to the small-scale R&D activity around TEMs (Investment needed: 76 570 euro)
  - Building the R&D team (employment of one person from GANIL/chemistry laboratory with the capability to run the full TEM production process (i.e. beam irradiation + chemical etching + material characterization)
  - Building the start-up company (potential funding from CEA and/or CNRS): employment of one dedicated business-oriented person with the technical and commercial capacity to start a communication process of the TEM activity in GANIL by:
    - promoting the global visibility of GANIL (BM1)
    - contacting companies interested in TEM technology (BM2)
    - starting social media profiles (e.g. LinkedIn, Facebook)
    - creating the website (for example by using the free online platform - WordPress)
    - probing the market by offering the free samples allowing to build a database of future customers with potential TEM applications.
  - Assumption: GANIL gives for free a few hours of the beamtime to R&D activity around TEMs
  - Actions to be taken on Year 1: application for the Normandy Incubator and HORIZON Europe funding.

  Revenue: 24 000 - 375 000 euro/year (BM1&BM2) + 50 % of the R&D funding (e.g. Regional Funding) + Internal money from CEA/CNRS GANIL/CIMAP

  Spending: 2 x 0.5 MY salary (37 000 – 72 500 euro/year) + ½ Annual Laboratory Operation Cost (7 500 – 10 000 euro/year)

  Balance Revenue/Spending: Highly depending on BM1/BM2 revenue – supposed to be 0

Year 2:

- Assumption: GANIL gives a few hours of the beamtime to R&D activity around TEMs; the price of TEM sample is 500 euro with minimum sale of 10 samples per year
- Start-up company accepted to Normandy Incubator based on application done in Year 1

Start-up company starts to sell the TEM samples and offers some free samples to companies

Revenue: 24 000 - 375 000 euro/year (BM1&BM2) + 50 % of the R&D funding (e.g. Regional Funding + HORIZON Europe Funding) + 5 000 euro/year (TEM sample sale)

Spending: 2 x 1 MY salary (75 000 – 145 000 euro/year) + Annual Laboratory Operation Cost (15 000 - 20 000 euro/year)

Balance Revenue/Spending: Highly depending on BM1/BM2 revenue – supposed to be 0

Year 3:

- Assumption: GANIL gives a few hours of the beamtime to R&D activity around TEMs; the price of TEM sample is 500 euro with increased sale of 15 samples per year
- The R&D program is fully running
- Start-up company is incubated in Normandy Incubator
- Start-up company sells the TEM samples

Revenue: 24 000 - 375 000 euro/year (BM1&BM2) + 50 % of the R&D funding (e.g. HORIZON Europe) + 50 % startup + 7 500 euro/year (TEM sample sale)

Spending: 2 x 1 MY salary (75 000 – 145 000 euro/year) + Annual Laboratory Operation Cost (15 000 - 20 000 euro/year) + Business Consulting (5 000 euro/year)

Balance revenue/spending: Highly depending on BM1/BM2 – supposed to be 0

Year 4:

- GANIL sells the beamtime to start-up company for a price of between 1 000 – 1 250 euro/hour
- Start-up company is incubated in Normandy Incubator
- Start-up company sells the TEM samples

Revenue: 24 000 - 375 000 euro/year (BM1&BM2) + 50 % start-up TEM sample sale

Spending: 2 x 1 MY salary (75 000 – 145 000 euro/year) + Annual Laboratory Operation Cost (15 000 - 20 000 euro/year) + Business Consulting (5 000 euro/year)

Balance revenue/spending: Highly depending on BM1/BM2 – supposed to start to make profit

Year 5:

- If no funding, end of the R&D program otherwise continuation of the R&D activity
- Start-up company sells the TEM samples
- Possible actions to be taken: start-up company seeks for an investor to build an independent facility for post-irradiation TEM treatment (i.e. chemical etching, material characterization and sample preparation) for commercial level production
- GANIL sells the beamtime to start-up company for a price of between 1 000 – 1 250 euro/hour

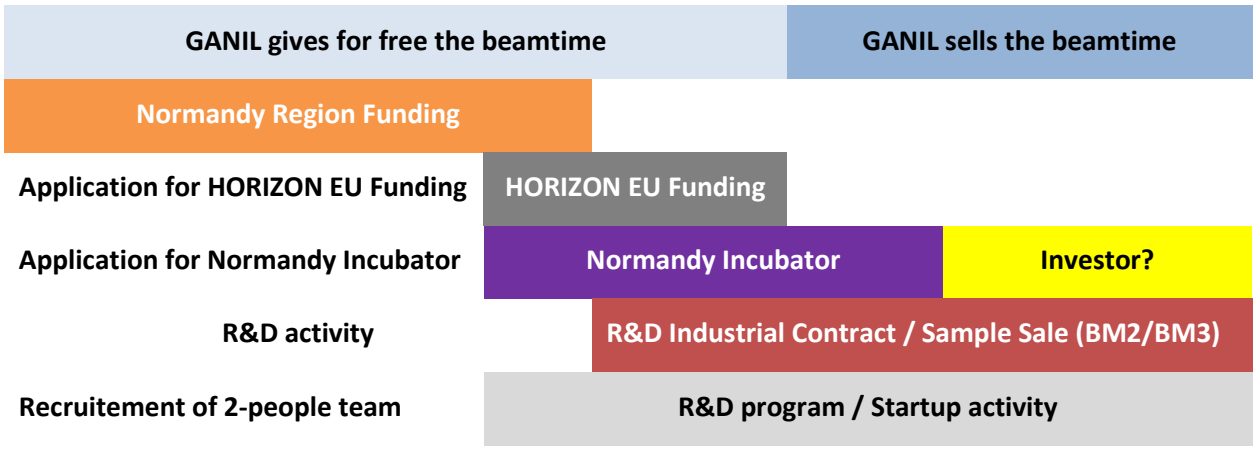
Revenue: 24 000 - 375 000 euro/year (BM1&BM2) + 50 % of start-up TEM sample sale

Spending: 2 x 1 MY salary (75 000 – 145 000 euro/year) + Annual Laboratory Operation Cost (15 000 - 20 000 euro/year) + Business Consulting (5 000 euro/year)

Balance revenue/spending: Highly depending on BM1/BM2 – supposed to make profit

Simplified synthesis of the 5-year Business Plan for Business Model 3

Year 0	Year 1	Year 2	Year 3	Year 4	Year 5



Initial investment needed to start the R&D activity with chemistry laboratory: **76 570 euro**

3.1.7. Research Project, Partnership & Funding Sources for Business Model 3

The BM3 proposed in the previous part requires building the first R&D project and a Start-up Company in GANIL/chemistry laboratory working on TEM subject. The third model is also a sum of BM1 and BM2 extended by the possibility of startup creation. Consequently, the substantial funding allowing to initiate such an R&D activity in GANIL has to be obtained. The location of the GANIL facility strongly suggests focusing on local funding sources promoting innovation and development in the Normandy region. The R&D activity in specific areas of interest such as agriculture; human & animal healthcare; or any ecology-related fields are well in line with the regional development strategy of the Normandy region. However, building such an R&D project leading to manufacturing of the ready-to-use TEM involves a two-step process: ion irradiation and the post-irradiation chemical treatment of the polymeric film. The first production step is an exclusive competence of GANIL but the second one may require a strategic partnership, either with a public or private sector laboratory bringing the competence in the post-irradiation TEM chemical treatment and potential application.

By accepting the BM3, the GANIL/Chemistry laboratory would have a chance to start its first R&D activity around the TEM allowing for further exploration of the market needs while exhausting the competitive advantage of the facility. Moreover, the partnership with the local laboratory or a company based in the Normandy region may help to ease the entire funding application process. An R&D project proposal, of 2-3 pages long, has to be formally written including the following parts:

- Project target and addressed social/economical demand to meet the regional needs
- Project description including the current state-of-the-art of technology and its novelty
- Project partners and their specific role in the R&D project.

Based on many possible TEM applications, the most promising future R&D topics for BM3 include:

- TEM as a thin, infra-red sensor (e.g. soft electronics, energy generation)
- Micro-hole porous TEMs for turbulent water friction reduction (e.g. kayak, boats)
- Beta-PVDF with piezoelectric properties for green energy generation (e.g. flags, masts)
- TEMs for virus detection and anti-viral applications (e.g. COVID-19 laboratory tests and virus de-activating filters for masks)
- Metal-coated (e.g. aluminium, platinum) TEMs exhibiting anti-fire properties (e.g. cars - Formula One, airplanes and spacecrafts).

Concerning the R&D partnership with GANIL, the list of potential institutions which might be interested in such a collaboration is being proposed:

- Research Centre on Ions, Materials, and Photonics (CIMAP) located in Caen and being in a privileged position for this development due to geographical proximity and close collaboration of research teams.
- École supérieure d'ingénieurs des travaux de la construction (ESIC) located in Caen
- Chimie Organique et Bioorganique – Réactivité et Analyse (COBRA) located in Rouen
- Institut Européen Des Membranes (EIM) located in Montpellier.

Please, note that the list is only a suggestion and can be modified or even further expanded by other potential partners in a free manner. The only requirement which has to be met by an external institution is the level of expertise in the chemical etching, complementary to GANIL'S competence necessary to build a complete and innovative R&D activity around TEMs.

Apart from the local funding sources favourable towards new R&D activity in the Normandy region, other national financial sources can also be considered, such as:

- **The French National Research Agency (ANR)** is a public administrative institution under the authority of the French Ministry of Higher Education, Research and Innovation. The agency funds project-based research carried out by the public sector cooperating with private companies: https://anr.fr/en/anrs-role-in-research/missions/ (Accessed: 29.09.19).
- **European Innovation Partnership (EIP-AGRI)** foster competitive and sustainable farming and forestry that 'achieves more and better from less'. It contributes to ensuring a steady supply of food, feed, and biomaterials, developing its work in harmony with the essential natural resources: https://ec.europa.eu/eip/agriculture/ (Accessed: 29.09.19).
- **Enhanced European Innovation Council (EIC)** pilot aims to support top-class innovators, startups, small companies, and researchers with bright ideas that are radically different from existing products, services or business models which are highly risky but have a potential to scale up internationally: https://ec.europa.eu/programmes/horizon2020/en/h2020-section/european-innovation-council-eic-pilot (Accessed: 18.02.20).

3.1.8. CONCLUSION ON THE BUSINESS PLANS PROPOSED FOR THE TRACK-ETCHED MEMBRANE ACTIVITY

This study has been performed with the aim of proposing to the future GNAIL directorate, several possibilities for the development of TEM activity at GANIL. The various business models and business plans can answer to the different ambition levels that can be imagined for the development of more innovative activities at GANIL.

3.2. BUSINESS MODEL AND BUSINESS PLAN FOR THE ELECTRONIC COMPONENT IRRADIATION ACTIVITY

3.2.1. ESTIMATED COST FOR ELECTRONIC COMPONENT IRRADIATION ACTIVITY

The fixed costs for electronic component irradiation at GANIL's facility, calculated for 8 hours and 1 hour of continuous beam operation, have been evaluated according to IDEAAL/WP3 modelling. This modelling needs to be completed by the introduction of depreciation rates, but in the case of the whole equipment used for this activity, the depreciation rate will be rather low as the main equipment was built in 1987 and is fully amortized now. One equipment (sample holder) was added in the 2000' and was financed by a loan from the BPI (Banque Publique d'Investissement) and has been reimbursed since then by the industrial users (reimbursement included in the beam price of the last years).

Staff relates to all people working in GANIL's facility during the beam irradiation experiment.

Only the CSS1-CSS2 operation is considered for electronic component irradiation activity, as the activity is focused on high energy and high LET heavy ion beams (cf. § 2.1.1).

CSS1 CSS2	Price with staff	Price without staff
GANIL's Real Cost of Operation per Single Unit (1 UT = 8 hours)	56 000 €	17 000 €
GANIL's Real Cost of Operation per One Hour	7 000 €	2 125 €

For the electronic component irradiation, an additional percentage is added in the beam hourly price, which corresponds to an average contribution to the beam tuning time by all the users using the same beam on a given beam slot.

One has to consider also the "market" price among the European facilities able to produce these beams, and to be careful also with the international market price: over a given hourly price, it is more interesting financially to choose American or Asian facilities, even including the travel costs.

The chosen price will be the price without staff, as GANIL does not pay any permanent staff.

3.2.2. CURRENT BUSINESS MODEL OF GANIL FOR ELECTRONIC COMPONENT IRRADIATION

The GANIL's revenue from the electronic component irradiation activity comes exclusively from selling the beamtime to industrial users. No new scheme has been studied, as no research activity in this field is foreseen in the GANIL future activities, regarding development of electronic component to be used under irradiation. And the necessity of creating such an activity was not identified as a potential innovative activity for GANIL future.

The present business model will be then kept in the future, and the beam time price will be regularly adapted according to the general market price. The present priority is to work on increase of the beam availability as, because of this lack of beam time, developments are ongoing for the search of new means of testing electronic components. These new developments might lead in the future to decrease or complete stop of use of the charge particle beams for component testing.

4. CONCLUSION

This report contains important information on the past, present and possible future industrial activities at GANIL, regarding the electronic component irradiation and the track-etched membrane production. These fields have a secure future for at least the next six to ten years, and regarding the track-etched membrane proposed project, the development of a new R&D activity in collaboration with a chemistry laboratory, associated to a production activity, could bring the GANIL facility in the yard of research facilities valued for their applied research.