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EUROPEAN NUCLEAR SCIENCE AND APPLICATION RESEARCH 2

GRANT AGREEMENT NUMBER: 654002

D 8.1 - INTERMEDIATE INNOVATION SURVEY REPORT

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List of acronyms and abbreviations

IORT	Intraoperative radiation therapy
PET	Positron Emission Tomography
PLIF	Planar Laser-Induced Fluorescence
DAQ	Data AQuisition

Workpackage WP8 NuPIA (Nuclear Physics Innovation) is a transversal network activity meant to reinforce the partnership of Nuclear Infrastructures and Institutions with Industry and to promote the use of Nuclear Physics Infrastructures by industrial researchers. It is also a link between innovation officers of the institutions, research groups in various ENSAR2 WPs and industry.

WP8 has been divided into 3 tasks, as listed below:

- Task 1: Survey of innovation within the ENSAR2 WPs (coordinator: CEA)
- Task 2: Bridging and Dissemination (coordinators: UniWarsaw, GANIL)
- Task 3: Training in nuclear techniques: schools for employees of industrial companies (coordinators: JYU, ULIV)

NuPIA Task 1 – Survey of innovation within the ENSAR2 WPs (CEA)

The objective of this task is to highlight the innovative capacity of the ENSAR2 partners and quantify the impact in terms of direct and indirect benefits for industry and society. For this purpose, a survey of the innovative developments done within the different ENSAR2 WPs of possible interest for industry or other scientific domains is being carried out. The first work consisted in defining the methodology and choosing the impact indicators.
The impact indicators adopted for this Task concern the potential or established benefit for both industry and other domains of science that could arise from the technologies developed within ENSAR2. They are examples and/or numbers of:

- Innovation of interest for industry or other domains of science
- Technology Transfer
- Patents
- Licensing
- Valorization/selling (to other labs or to industry) of products developed for our physics.

The WPs in which there are possible innovative developments have been identified (see Table below) and the list of corresponding WP leaders and associated TT officers prepared. A questionnaire containing the chosen impact indicators has been sent to them.
This work is complementary to the survey of the innovative capacities of the ENSAR2 infrastructures done in Subtask 2.2 and to the general impact study carried out in WP FISCO2 on the regional social, economic or environmental benefit arising from the presence of the ENSAR2 research infrastructures.

- **Innovation in WPs**

WP	Innovation	Contact	email
NA3 – MIDAS: MInimisation of Destructive plASma processes in ECRIS.	bringing together research teams developing ion sources and beams for the needs of these facilities, and industrial partners	Hannu Koivisto (JYU)	hannu.a.koivisto@jyu.fi
NA4 – NUSPIN: NUclear Spectroscopy Instrumentation	building of bridges between the scientific developments and the applications for the society.	Silvia Lenzi (INFN Padova)	Silvia.lenzi@pd.infn.it

NA5 – MediNet: Medical Network	research on beam-delivery methods, large-area transmission detectors, improved imaging technology, and reliable online dosimetry with potential involvement of industrial partners.	Peter Thirolf (LMU)	Peter.Thirolf@lmu.de
NA7- ENSAF: European Network of Small-scale Accelerator Facilities.	workshop dedicated to Physics Opportunities and Innovation at European Small-Scale Accelerators	Sotirios Harissopoulos (NCSRD)	sharisop@inp.demokritos.gr
JRA1 – PASPAG: Phoswich scintillator assemblies: Application to the Simultaneous detection of PArticle and Gamma radiation	Applications of novel scintillator materials for societal applications, for example, within the areas of nuclear medicine and homeland security.	Olof Tengblad (CSIC)	olof.tengblad@csic.es
JRA2 – PSeGe: R&D on Position-Sensitive Ge Detectors for Nuclear Structure and Applications (CSIC).	Demonstration of imaging applications and associated detector technologies for medical applications.	Andres Gadea (CSIC)	andres.gadea@ific.uv.es
JRA4 - RESIST : RESonance laser Ionisation Techniques for separators .	Investigation of new concepts for solid-state laser technology can interest industrial partners.	Iain Moore (JYU)	iain.d.moore@jyu.fi
JRA7 – TecHIBA: Technologies for High Intensity Beams and Applications	Radio-Isotopes for Therapy and Medical Imaging; Generic Electronics Systems	Giuseppe Verde (CNRS/IPNO)	verde@ipno.in2p3.fr

The leaders of the WP that have been identified as possibly leading to technological developments that have led or could lead to technology transfer have been contacted. Up to now and although the work within ENSAR2 is still in progress, already two WP have obtained results interesting industry.

NA5 – MediNet: Medical Network

This network is gathering laboratories doing research on beam-delivery methods, large-area transmission detectors, improved imaging technology, and reliable online dosimetry in relation to hadron therapy and other nuclear medicine applications. The goal is to develop tools that could be transferred to industrial partners. Some technology transfers have already been identified.

Universidad Complutense de Madrid (UCM, Spain) has developed:

- a Monte Carlo and hybrid algorithm for phase space generation and fast dose calculations for Intrabeam IORT, electron IORT and high rate brachytherapy, which has been licensed to GMV (multinational company) and is working on extensions to different devices.

- prompt gamma ray / in beam PET monitors for range verification in proton therapy. UCM is presently drafting agreements with the future proton therapy centers in Madrid.
- preclinical PET detectors, DAQ system and reconstruction software, which have been licensed to SMI, present in scanners all over the world. They continue working on the extension to real time PET imaging and motion correction.

IPN Lyon/ LPSC Grenoble (France)
The French collaboration, gathering labs from Lyon, Grenoble, and the Centre Antoine Lacassagne in Nice, developed a method for online control of proton therapy, called prompt-gamma peak integral (PGPI). The basic idea is that the total number of prompt-gamma photons issued from the patient, and detected at a given position, depends on the total energy deposited in the patient, and on the relative positions of the beam and the detector. A set of detectors located at different positions may enable to detect beam position and beam range variations. In comparison with prompt-gamma imaging devices, this method is quite simple and affordable. A French patent has been submitted in 2016.

The principles and the first results of feasibility studies have been published [1] and presented in various international conferences. Presently the academic partners are searching for an industrial partner for clinical valorization.

[1] A cost-effective monitoring technique in particle therapy via uncollimated prompt gamma peak integration, J. Krimmer, G. Angellier, L. Balleyguier, D. Dauvergne, N. Freud, J. Herault, J.M. Letang, H. Mathez, M. Pinto, E. Testa, Y. Zoccarato, Applied Physics Letters 110, 154102 (2017)

JRA4 - RESIST : RESonance laser Ionisation techniques for SeparaTors

Within RESIST, one of the tasks, led by KU Leuven, is to develop well-collimated supersonic gas jets in order to realize the optimal spectral resolution for laser spectroscopy close to the gas cell from which exotic short-lived radioisotopes are produced and extracted. Following expansion from the gas cell the temperature and flow density drop dramatically, and an ideal environment for high resolution laser spectroscopy with minimal environmental disturbances to the atomic line profile is achieved. To maximize the benefits of such spectroscopy the gas cell parameters and nozzle have to be carefully chosen, requiring detailed studies of the gas jets. This has been achieved using the technique of Planar Laser-Induced Fluorescence (PLIF). Such a method involves the seeding of heavier atoms into the gas jet, the subsequent laser excitation of the atoms followed by detection of the photons emitted during de-excitation. Information on the density, temperature and velocity of the profiles may be extracted and, later, compared to fluid dynamics simulations.
Recently, researchers at the Von Karman Institute for Fluid Dynamics in Brussels have been approached for their expertise in calculations for the optimization of de Laval nozzle contours required to reach high Mach number and uniform gas flows. These researchers were immediately interested in the use of the PLIF technique which can provide the local temperature in different regions of the flow. This is currently impossible to obtain from their measurements. Such information is of primary interest for the design of high Mach number nozzles (hypersonic flows), and could have a great impact in the design of high speed planes, rockets etc. The applicability of such research to industry or technology is obvious.
In summary, the current and future characterization of hypersonic nozzle (M>5) performed at KU Leuven, within the RESIST activity, has important implication for society and industry.

The collection of activities or technical developments done in the WPs of ENSAR2 that have led or could lead to technology transfer will continue through the interrogation of technology transfer officer of each lab.