ANDROMEDE (ANR 10-EQPX-23)

https://andromede.in2p3.fr/

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IJCLab

1. Presentation

The Andromeda project [1] is a platform for analysing the properties of matter at a sub-micrometric scale. It uses a high-energy (4MV) electrostatic accelerator built by NEC Pelletron®. Two ion sources are used, a liquid metal ion source (LMIS Liquid Metal Ion Source) for cluster or nanoparticles beams with several hundred atoms, and an electronic cyclotronic resonance source (ECR) for atomic and molecular beams. The main instrument associated with this accelerator is a high-resolution EVE mass spectrometer that enables sub-micrometric ionic imaging of surfaces. The project brings together a consortium constituted by Orsay Physics, a company with expertise in ion sources and columns located in Fuveau (South of France), and scientists from the Paris-Saclay University and CNRS. These are biologists from I2BC[1], chemists from ICMMO[2], physicists from IJCLab and ISMO[3] and astro-chemists from IAS[4], as well as nuclear physicists from IPHC[5] in Strasbourg.

Andromeda is in operation since 2017. It is fully equipped with two beam lines, one line at 1.29° and one line at 90°. The first line is dedicated to surface analysis by nanoparticles (EVE). The 90° line is dedicated to experiments using atomic and molecular ions of light masses. Two equipment have been installed, one for nuclear astrophysics (named STELLA) and a second for astrochemistry experiments with molecular beams (AGAT). On this line two new experiments are being set up. The first, TAMARIX, will study the energy loss of light ions in complex solids to improve the accuracy of IBA measurements, in collaboration with a team from the University of Science and Technology Houairi Boumédienne in Alger. The second, the NanoCR experiment will study the interaction of high-energy ion beams with nanoparticle beams, carried out by LEDNA (Laboratoire Edifices Nanométriques, CEA-CNRS-UPSaclay) with which a collaboration is initiated (IPNO, CSNSM, CNRS-IN2P3-Upsaclay, ISMO, CNRS-INP-UPSaclay). At 1.29° the EVE beam line, for applications in biology and exobiology, was set up and 100 µm cluster beams were used to analyse the first biological samples as well as meteorite analogues. New applications of surface analysis for the Large Hadron Collider of CERN were also initiated with the IJCLAB Vacuum and Surfaces team (formerly LAL). During the ten years of the EQUIPEX project, the Andromeda Consortium has expanded through national and international collaborations, with the Luxembourg LIST[6] for source developments (which led to two PhD thesis in co-direction), with the LAEC of Beirut in Lebanon for pharmaceutical and astrochemical studies, (collaboration that also led to the defence of a doctoral thesis) and also with the team of Professor E. A Schweikert in Texas A&M University with whom collaborations were established around the interaction Nanoparticle-Surface since the installation of the Pegase Project developed at the IPNO under my responsibility and installed in TAMU [2].

[1] I2BC : Institut de Biologie Intégrative de la Cellule
[2] Institut de Chimie Moléculaire et des Matériaux d'Orsay
[3] Institut des Sciences Moléculaires d'Orsay
[4] Institut d'Astrophysique Spatiale
[5] Institut Pluridisciplinaire Hubert Curien
[6] Luxembourg Institute of Science and Technology

The Andromeda project began in 2011 and was completed in December 2019. It obtained €4 million over this period, €3 million for equipment and €1 million for operations. A 2-year postdoc has been supported by the Labex P2IO (€100k) to develop the proton and electron emission microscope that equips the EVE mass spectrometer in collaboration with the TAMU team [3]. This microscope enables us to locate impacts in the sub-micrometric range. Andromeda was received in 2015 and temporarily installed in the University's Super ACO Hall. It was approved for operation by the ASN in April 2016. This authorization was renewed until March 2021. The facility is shown in Figure 1.

Figure 1: The Andromeda platform

The future IGLEX building that will house the EQUIPEX THOMX (driven by LAL) and Andromeda in 2020 was realized in 2015-2016 thanks to the CPER funding. The budget includes the adaptation of the building and the installation of the nuclear safety system, the amount currently invested is €3 million. An ANR funding for further source developments was obtained with two partners from the ICMMO Consortium partner and Orsay Physics. This budget of €267.8K is essentially devoted to pay a 2 years postdoc position (Project Hibiscus-ANR-17-CE09-0023) from 2018 to 2020.

Andromeda received the IN2P3 platform label since November 2017. This implies an annual COPIL meeting (operated since 2018) and a Program Advisory Committee (PAC) consisting of a consortium partner and 3 external members (**C. Briois** Associate professor at Loire Valley University of Orléans, Earth Science (OSUC) Department,Co PI of Cosima Mission; **I. Fournier**, Professor IUF Senior at University Lille 1, Prism Laboratory INSERM, Assistant Director of Federative Research Institute IFR 147, **O. Stephan**, Professor of physics at University Paris-Sud and an honorary member of the Institut Universitaire de France). There is a meeting once a year.

The scientific strategy and the priorities in terms of use and evolution are defined by the scientific coordinator, Serge Della Negra, CNRS Research Director. The proper functioning and management of all the resources of the platform are ensured by the operational manager. Currently this role is provided by interim by Isabelle Ribaud, Research Engineer at CNRS. A position of assistant engineer at Paris-Saclay University is in the process of being made permanent to assist the RO in the start, adjustments and operation of the accelerator. Tables 1 & 2 summarize the evolution of human resources and the needs of Andromeda. Annexe 4 describes the IJCLab

organization chart and participation of Andromeda in different networks. Annexe 5 gives the delivered beam time since 2016.

Table 1: RH Andromède - November 2019

Function	RH	Status	Contribution	FTE	Comments
Operational Manager	In progress	Permanent	Platform /Andromede	0,3	Urgent recruitment (departure of Jean Lesrel)
Engineering Assistant	F. Daubisse	CDD	Platform /Andromede	1	University 01 à 12/2020
Scientist Leader (DR)	S. Della-Negra	Permanent	Platform/NIM Research and education	0,3 0,7	Eméritat March 27, 2020 Demand 3 years ago (MdC)
Researcher (DR)	D. Jacquet	Permanent	NIM Experiments Research and expertise Scientist	1	Retirement 2021 or 2022
Scientific engineer	I. Ribaud	Permanent	Scientific and technical expertise /NIM coordination/Quality/animation	0,7 0,3	
Post-Doc	T.L. Lai	Post-Doc	R&D/NIM Scientific experiments	1	End of contract: march 2020 Project ICMMO/IPNO: Polyions in progress
Doctorant	L. Amari	Thèse	R&D/NIM Scientific experiments	1	End of contract : September 2020
Administrative Assistant	J.Y. Zana	Permanent	Administrative	0,02	In Progress
Project Management	V. Poux	Permanent	Platefrm/ Project monitoring	0,02	For 2012

Table 2: Support for Andromede, interactions with support services

Contribution in 2019	FTE	Permanent IJC Lab
Computing, C&C	1,02	J.L Coacolo, N. Dosme
Mechanics	0,52	P. Blache, B. Mathon
Electronics	0,18	J.F. Yaniche
Operational Manager	0,5	J. Lesrel (avant sept.2019)

The 2018-2019 budget is summarized in Table 3 below:

	Expenses		Revenues		Balance
	Item	**Amount €HT**	**Types of funding**	**Amount € HT**	
Andromède	Maintenance	47	Equipex * taken over by the IJC Lab	90 k€	Provision for removal costs 2019-2020. 28 k€
	general operating expenses (missions, …)	3			
	Infrastructure	20*			
	Others	12			
Project TAMARIX	Equipment	2	Franco Algerian program Thassili		Balance
			2 k€ (2018)/6.75		
	Personnel management fees	6.75(2018) 8.1 (2019)	0.6 k€ (2019)/8.1		
Projetc Hibiscus	Aid allocated by OP	91,5	Recruitment	103,3 k€	Profit : 20 k€ (Contract extensions CDD)
	Aid allocated by ICMMO	32,4	Instruments and supplies	23,5K€	
	.		General operating expenses	6,5 K€	
			Personnel management fees	10,7	
IGLEX	Installing a security system	272,9 k€	CPER+ Andromede (3 k€ maintenance of fire protection systems)	666 k€	Balance
	Radiological protection system	381,7 k€			
	Laboratory fume	11,3 k€			
	Others	3 k€			

The 2020 endowment request is € 22.4k for Andromede in operation. This sum corresponds to current operation (consumables and small specific equipment, maintenance, acquisition of a remote-control system). It also includes the financing of a trip to NEC to prepare for the move + factory equipment control: € 5k / 2 weeks-1 person). The infrastructure (mainly electrical power) is taken care of by the authorities (IJCLAB, University of Paris Saclay). (Table4)

	Spendings	
	Item	Amount k€ HT
Andromede	Operational costs	22,4
	Missions	5
	Infrastructure	20
	Other item	10
IGLEX	In progress	

Comments

- Andromede Operational costs /IN2P3 : 22,4 k€
- NIM /General expenses :5 k€
- Infrastructure : Université Paris Saclay /IJCLab 20k€
- Other Item : contribution to pooling equipment (Multi-analyser SF6)

Relocation
150 k€ (estimate via StateRegion Plan (CPER)

Table 4: Budget 2020

This year is special for Andromède because of the move of the platform, from SuperAco to IGLEX within the framework of the CPER. This implies a shutdown period in 2020 which is not fixed because it is linked to ASN authorization. Note that equipment maintenance has been anticipated for 2020 as part of the closing of Equipex, the move being initially scheduled for the end of the year

The cost of the maintenance of the platform was estimated at 40 k€/year and an estimate of the price of the bundle hour was also calculated for payment of the users in the case of service.

This calculation incorporates personnel management fees (€13,023/8 months which corresponds to the 2.5 FTE for the operation of the accelerator), equipment depreciation (€3 million) €200,000/8 months (Base of 120 months, 10 years.), operating expenses €40,000 + €20,000 (fluid estimate and electricity), resulting in an hourly cost with amortization:

For outdoor	Academic (no staff costs)	Partners/IN2P3
360 €/h	203 €/h	0€/h

2. Scientific results

a. Atomic and molecular beam experiments

i. STELLA Collaboration IPHC, IPNO, GANIL, CSNSM, Université de York (UK), Université de Surrey (UK), STFC Daresbury (UK), Université de Aarhus (Danemark), laboratoire National de Argonne (USA).

IPHC web page : http://www.iphc.cnrs.fr/STELLA.html

The $^{12}C+^{12}C$ fusion reaction plays a key role in the evolution of massive stars and impacts various explosive astrophysical scenarios. The presence of resonances in the reaction around and below the Coulomb barrier make it impossible to carry out a simple extrapolation down to the Gamow window – the energy regime relevant to carbon burning in massive stars. The $^{12}C+^{12}C$ system therefore forms a unique micro-laboratory for challenging the contemporary picture of deep sub-barrier fusion (possible sub-barrier hindrance) and its interplay with nuclear structure (sub-barrier resonances). Here we show that direct measurements of the $^{12}C+^{12}C$ fusion cross-section may be made into the Gamow window using a particle-gamma coincidence technique. The sensitivity of this technique effectively removes ambiguities in existing measurements made with gamma-ray or charged-particle detection alone.

To carry out these experiments, IPHC constructed a dedicated measurement station called STELLA, which was mounted on a beam line at the Andromede accelerator facility This realization was supported within the framework of the Initiatives of Excellence (IdEx, Investissements d'Avenir 2015) of the University of Strasbourg, by the CNRS (IN2P3) and by the Institute of Advanced Studies of the University of Strasbourg (http://www.usias.fr/en/projects/projects-2015/life-cycle-of-stars/) and by the University of York (UK). The STELLA set-up comprises a vacuum chamber containing a rotating target mechanism which supports large diameter (~ 5 cm) thin (~ 200 nm) natural carbon foils which can be rotated at up to 1000 rpm to efficiently dissipate heat from the intense ^{12}C beams and hence, prevent target deterioration allowing for measurements over many days. Charged particles are detected in three annular silicon strip detectors covering 30% of 4π solid angle. For gamma-ray detection, STELLA employs an array of 36 Lanthanum Bromide ($LaBr_3(Ce)$) scintillator detectors from the UK FATIMA collaboration.

The data from the first experiments were analysed and led to the defence of a thesis in September 2018 in Strasbourg. An article presenting the final results are being submitted. The results identify three distinct regimes in the sub-Coulomb range: (i). The moderate sub-barrier regime – above $E_{rel} = 4.5$ MeV - where it has been possible to unambiguously validate our experimental concept by accurately measuring a strong known resonance in the $^{12}C+^{12}C$ fusion reaction, (ii). The deep-sub-barrier regime –from $E_{rel} = 4$ *to* 2.5 MeV- where the Fowler standard extrapolation systematically overestimates the results and where hindrance is observed. (iii). The 25 solar masses

Gamow window - below E_{rel} = 2.5 MeV - where the *S* factor rises up and may indicate a change in the fusion mechanism.

STELLA was highlighted in a IN2P3 /CNRS news flash in 2017 (http://www.in2p3.fr/recherche/actualites/2017/breve_STELLA.html) and *publicized widely to the public* by 4 presentations at the Strasbourg Planetarium in 2016. In 2016, the project was also the subject of 2 seminars (Univ. Surrey, Univ. Of York, UK), a poster at the Nuclei in the Cosmos conference (Niigata, Japan, June 2016) and a guest talk at the Cluster 2016 conference (Naples, Italy, May 2016). In 2017, the first results were presented at the Fusion 2017 conference (Hobart, Australia, February 2017). The presentation won the Zagrabaev-Gomes Young Researcher 2017 prize. A technical article was submitted in early 2018.

ii. AGAT collaboration (IJCLAB, ISMO, Universidad Autonoma Madrid, Paul Sabatier University Toulouse III, PI M. Chabot IJCLAB)

In the interstellar medium, among the 200 molecules observed, the hydrocarbons are in abundance. The formation of hydrocarbons $CH_y^{(+)}$ is done between a C^+ and a hydrocarbon atom or molecule. Thereafter, these hydrocarbons are reacting between them to form bigger hydrocarbons. These hydrocarbons $CH_y^{(+)}$ are under a lot of different physical processes in the interstellar medium including the collision with an electron, the absorption of an ultra violet photon or a cosmic ray. They will be excited by these processes and gain excess energy they will liberate by fragmentation which leads to a redistribution of species. Therefore, a precise knowledge of the rate of reaction and of the branching ratios of the fragmentation is needed to do specific simulations in the chemistry of the interstellar medium. In order to document all these branching ratios, no matter the physical or chemical process at stake, we experimentally built semi-empirical breakdown curves which are the branching ratios of the paths of fragmentation as a function of the internal energy of the molecule. The experiment was done using the AGAT silicon multi-detector and the ANDROMEDE accelerator. $CH_y^{(+)}$ molecules produced at high velocity are collided with He atom at rest in the lab. Thanks to the experimental developments, all fragments, neutral or charged, are separately identified, allowing to resolve all fragmentation channels. Indeed, a new system based on a fast 64 channels sampler from the LAL (Wavecatcher) has been test with success in the last GASPARD experiment. It has now to be included in the architecture of the AGAT acquisition which contains, in addition to the outputs of planar silicon particle detectors and/or MCPs, a CCD camera which permits to detect the neutral fragments

Therefore, we have been able to measure fragmentation branching ratios for CH_y^{q+} (y=2-4, q=0-3) and the kinetic energy distributions of the neutral fragments. From the branching ratios, the kinetic energy distributions and the theoretical dissociation energies we built BDCs that revealed to be in accordance with the experimental branching ratios which already exists in the literature concerning the photo dissociation, the dissociative recombination and the electronic collisions.[4] Finally, a model has been developed to predict the chemical reactions of the branching ratios as well as to predict their evolution with the temperature.

These results were presented in the context of a thesis in September 2019 and were the subject of two articles.

b. ANDROMEDE-EVE Collaborations, Surface Analysis

The Andromeda platform is unique in the quality and range of beams it delivers. It enables several areas of research to be tackled with a multi technical environment. This instrument is used for very low energy nuclear cross section measurements and for the study of molecule-gas

interactions in astrochemistry. The core of the Equipex project concerns surface analysis associated with mass spectrometry and ionic imaging with cluster and nanoparticles beams. The interested scientific fields are numerous, they range from accelerators to cellular biology in relation to health. The knowledge of particle-matter interaction and the continuation of fundamental research with Andromeda allow to answer many multidisciplinary problems. In this context these new available beams are also particularly powerful to study materials modifications and synthesis under irradiation. Thanks to the intensive studies conducted in 2016-2017 with Andromeda, a very good reliability of the machine has been obtained, with excellent beam characteristics, from atomic ion beams to nanoparticle beams with projectiles of several hundred to thousands of gold atoms [1]. These beams, accelerated to several MeV, (from 2.5 to 12 MeV) were analysed and deflected by the magnet at 1°29 and reached the target placed at the centre of the EVE mass spectrometer. (Figure 2) Mass spectra were obtained with cluster beams having typical diameters of a few tens of µm, with intensity high enough for all the intended applications. (Table 5) The targets can be scanned over a surface of several mm² per nanometric displacement, the field view for each position is 500 µm.

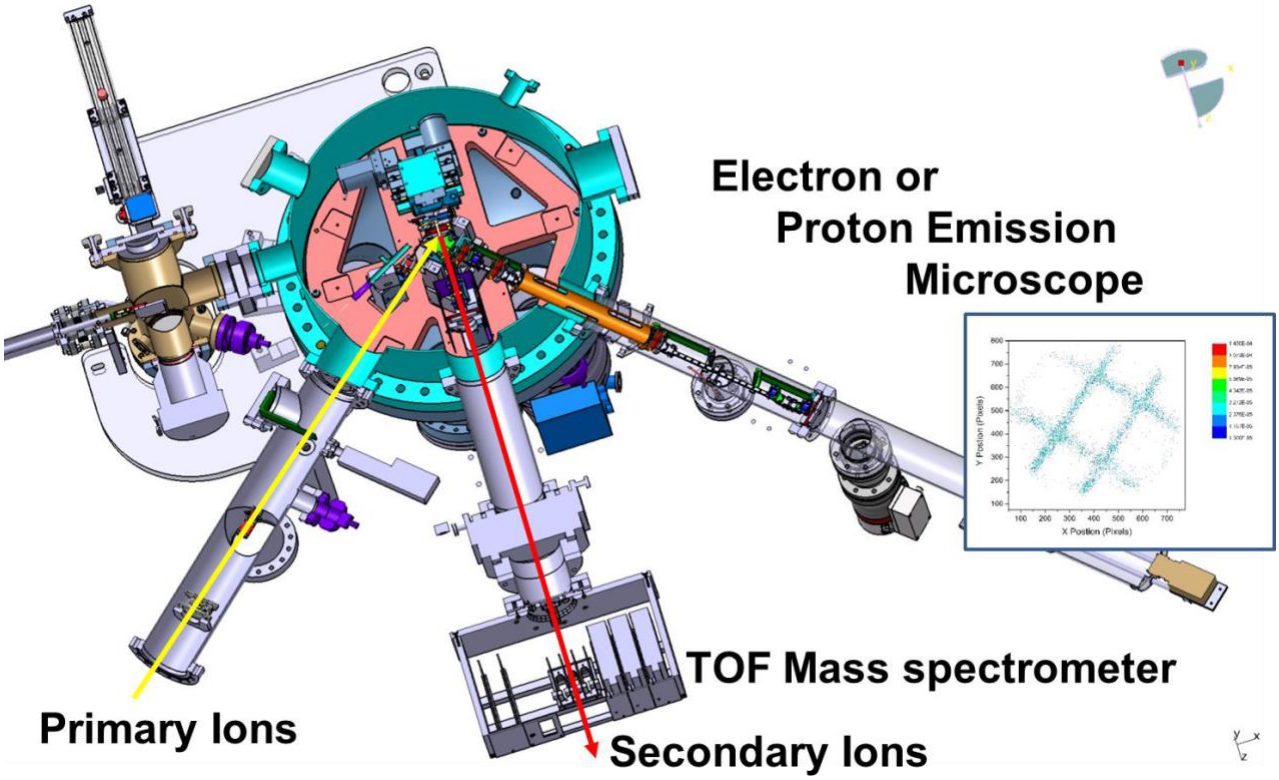


Figure 2: EVE Mass Spectrometer

Ions	Energy (MeV)	Intensity (nA)	beam size (µm) & Intensity (pA)
	@the exit of the acc.		In the centre of MSI EVE chamber
Ar^{q+}, q=1- 8	1-32	100-1000	
SF_5^+	1, 2, 3, **3.65**	150 (1000)	**50** **300**
Au^{2+}	1, 2, **3**	10	
Au^+	"	40	**10** **1000**
Au_2^+	"	4	
Au_3^+	"	3	**10 (200)** **150 (3nA)**
Au_5^+	"	0.2	**20** **20**
Au_{400}^{4+}	4-16MeV	0.5 à 1	**100 (400-800)** **10**
Au_n^{q+}, n = 120, 1600 atoms		0.1à 1	**400 (800)** **10**
Future beams for MSI Experiment			
C_{60}^{q+}, q= 1-3		10-100	

Table 5 Characteristics of the accelerated beams on the surface analysis line

a. Characterisation of the interaction of high energy nanoparticle beams

Fundamental studies were undertaken to determine the characteristics of secondary ion emission induced by the impact of nanoparticles accelerated in the MeV range. The experiments were mainly conducted with 12 MeV Au_{400}^{4+} beams. Graphene targets established that the impact of these ions induce very high interaction surfaces: the diameter of the holes induced by these projectiles in a foil consisting of a few monolayers reach almost 100 nm. This result was obtained by using the NION Ultra Stem 60 kV microscope of the LPS (Laboratory of Solid Physics) in collaboration with Luiz Galvao-Tisei and Fuhui Shao. (Figure 3)

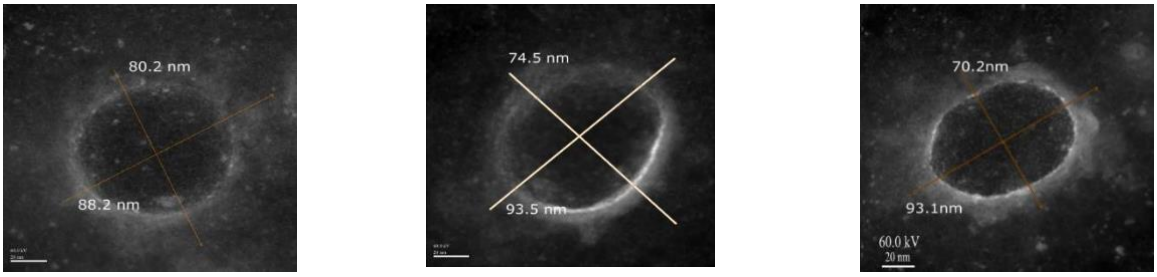


Figure 3: Measurement of traces induced by the impact of 12 Mev Au_{400}^{4+} in 6 ML graphene targets. The observation conditions are: Nion Ultrastem 200 operated at 60 keV, Beam settings: 30 pA current, 34 mrad half angle convergence, 350 meV energy.

This result is to be compared with the maximum diameter value of 10 nm obtained with cluster ions and nanoparticles in the 10-100keV range [5]. A second important point is the very high ion emission rate, in the reflection mode, although the thickness of these targets is less than or equal to nm. These secondary ions are emitted with the signature of the graphene target: carbon and carbon clusters of several dozen atoms, which is very surprising considering the velocity of the projectile and the dimensions of the sample.

The volume of ejected molecular material was also measured by performing a profile analysis of an irradiated polymer surface (PMMA). A thickness of 100 nm of this film was eroded

with only about 10^{10} projectiles, a dose about a thousand times lower than the usual doses for this type of analysis. The average volume of material ejected by impact reaches 10^6 nm^3, which somehow explains the high observed emission yields, which is one of the main advantages of these new probes. The most striking point is that during this irradiation, the mass spectrometry analysis of the irradiated surface shows no change. The mass spectra are unchanged, the residual film is still intact; there is very little degradation of the underlying molecular layers. These high ejection rates of 10^6 nm^3, which means a typical radius of a hundred nm by 10-20 nm depth, will allow depth profile measurements, over several hundred nm of organic material without losing molecular information which appears as a decisive advantage for biological sample analyses. A 3D image can thus be obtained with microbeams and/or microscopy by electronic or protonic emission installed on EVE.

The last essential features for surface analysis are secondary ion emission yields and ejection processes. Ion emission yields are hundred to a thousand times higher than those of commercial probes, regardless of the sample type and the polarity of the emitted ions. This huge increase is fully consistent with the above characteristics of the emission volume and track size in the targets. To go further in the understanding of the processes responsible for these huge emissions, the axial, radial and angular velocity distributions of the emitted ions were measured using the multi-pixel detector of the time of flight mass spectrometer. These data are still under analysis. First results indicate the presence of at least three emission mechanisms that occur sequentially during the penetration of the nanoparticles into the material, involving a pressure wave at the surface of the material and thermal processes.

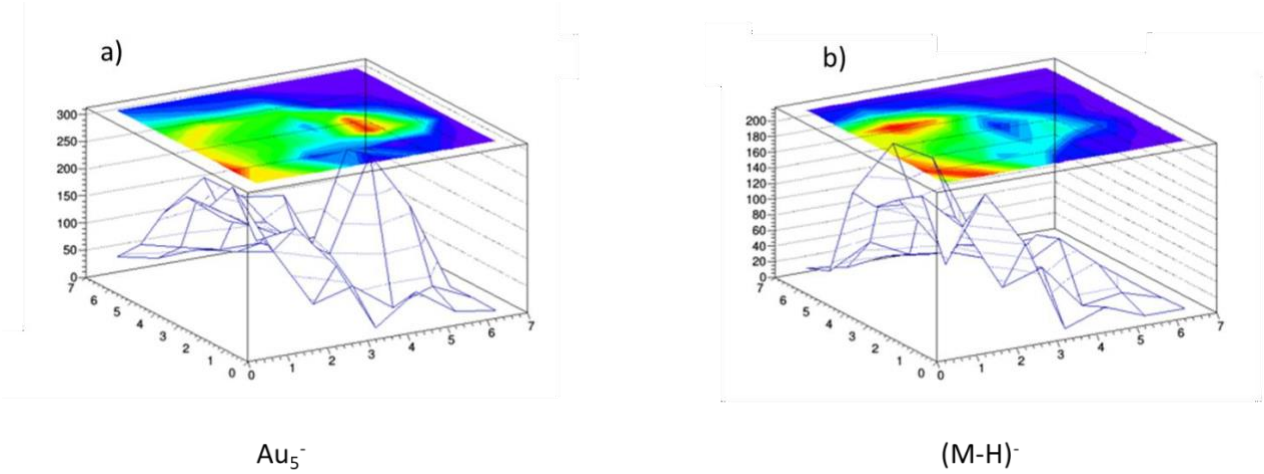


Figure 4: Angular distributions of the gold cluster Au_5 4 a) and the molecular ion of bradykinin (1060 Daltons) 4 b)

This emission is similar to the one occurring during the impact of a meteorite on a planet and described with a curtain-type emission of ejectiles, the evaporation of liquid material due to the heat generated by the impact and the bounce of the shock wave which creates the ejection perpendicular to the surface. The analysis also made it possible to distinguish the emission of molecular fragments that are emitted in the direction of the beam. These results are important for modelling the ion-matter interaction but also for adapting the secondary ion line to ensure the detection of all emitted ions. These results were presented in October at the International Conference SIMS22 in Kyoto and in a seminar at the IJC LAB on last January.

b. First multidisciplinary experiments

Gold nanoparticle beams with a n/q (n being the gold atom number and q the charge) ratio ranging from 40 to 160 were used to perform the experiments proposed at the last PAC.

a. In collaboration with the team of P. Tissière « Endotoxins Structures and Host Responses » in I2BC, we started the analysis and characterization of lipopolysaccharides (LPS) that are the

bacterial endotoxins responsible for infection. Protocols for detecting LPS via lipidA (mass 1300-1800 Daltons) have been validated. Ion yields are hundred times higher than those obtained with commercial probes using 25 keV bismuth aggregates. With at least one molecular ion emitted by impact, tissue and even cellular studies may be considered. For these tissue studies, slices of rat brains, were prepared and deposited on ITO blades. The first mass spectra on these samples were successfully obtained.

b. With the team of Prof. E. A. Schweikert from Texas A&M University, two series of experiments were carried out with Andromeda to test the use of halide markers for the detection of conjugated antibody-proteins. Three molecules with different halides (fluorine, bromine and iodine) were tested as individual and mixed markers. We have demonstrated the ability to measure several co-located proteins on an area of less than a few thousand nm^2 with a probability of 100 %. For these measurements the comparison with the 20-30keV clusters and 500keV gold nanoparticles of the Pegasus project [2] developed in collaboration with the IPNO demonstrates the remarkable efficiency of Andromeda with more than one order of magnitude in the emission yields. A second comparison in collaboration with Alain Brunelle of the LAMS using a commercial mass spectrometer IONTOF V (one of the most efficient commercial probe) showed a gain of a factor 1000 per single impact.

c. In collaboration with the group “Vacuum and Surfaces” of B. Mercier of the IJC LAB within the framework of the thesis of S. Bilgen, we investigated the elementary analysis and the characterization of copper, aluminum and stainless steel sample surfaces resulting from various preparations (cleaning, electronic bombardment, etc.) in order to understand the secondary emission processes disturbing the accelerating fields, in particular at the CERN LHC. In this context, the advantage of nanoparticle beams has been demonstrated, on the one hand with the high detection efficiency for molecules deposited in very small quantities on metal surfaces (lower than the monolayer) which gives access to sensitivities unreachable with commercial probes, on the other hand thanks to the analysis of the secondary cluster ions from the metal itself which allows to determine the chemical composition on the surface, allowing the determination of the metal ion oxidation state (in the present case for Copper) . These studies were extended by analyzing these surfaces after conditioning, ie irradiated with electron beams, and we were able to demonstrate that a film of hydrogenated graphene covers the irradiated surface. These results, which shed light on the conditioning process observed - and used during accelerator preparating runs – with increasing performance of accelerating devices with operating time, were presented at the international conference IBA (Ion Beam Analysis) this year and were awarded the prize for the best oral presentation by SFV.

d. The fourth item concerns the on-going collaboration with the IAS team "Astrochemistry and Origins" of D. Baklouti and R. Brunetto aiming to characterize the organic matter found in the carbonaceous chondrite in meteorites. The first phase of the project began with the analysis of mineral analogues of the matrice constituent of these carboneous meteorites. Molecules and organic materials of macromolecular structure, up to around 1000 u, were added by infiltration with different concentrations to simulate the organic / mineral mixture of extraterrestrial carbonaceous meteorites. The first measurements on Andromede showed a successful detection of this infiltrated organic molecule, allowing to start a refining phase of the sample preparation protocols and measurements. This work, started with a master2 internship, continues in 2019, with a PhD thesis within the IAS team.

The overall results were presented at three conferences in September and October 2019: a keynote at SMAP 2019 in Strasbourg (September 16-19, 2019), a poster at the IBA 2019 Antibes (October 13-18, 2019) and finally a presentation oral presentation at the Kyoto SIMS22 international conference (20-25 October 2019). In the appendix are provided the presentations and communications around the developments of Andromeda and the feasibility study carried out with

TAMU and Pegasus which was the subject of a collaboration where S. Della Negra was Co-PI (Grant NSF CHE -0,750,37)

3. Scientific Perspectives

a. Atomic and Molecular Beam Experiments

i. STELLA Collaboration (IPHC Strasbourg, Surrey University, York University, GANIL, PI S. Courtin)

Following the results obtained with the C + C experiments carried out in 2017-2018, the Stella collaboration will continue this research path by measuring lower energy reaction cross sections close to the Gamow peak and exploring other important reactions such as $^{16}0 + ^{12}C$ and $^{16}O + ^{16}O$. A new PhD thesis will be associated with the pursuit of these experiences.

ii. NANOCR Collaboration (LEDNA (Laboratoire Edifices Nanométriques, CEA-CNRS-UPSaclay, IJC LAB CNRS-IN2P3-UPSaclay, ISMO, CNRS-INP-UPSaclay, PI LEDNA)

In this project, it is proposed to cross, for the first time, a beam of controlled nanoparticles from a few nano-meters to a few tens of nano-meters, with an ion beam of a few tens of MeV. This experiment permits to explore the relation between the production of electrons and fragmentation and the size of the nano-system and the stopping power of the ion. This experiment aims to demonstrate the feasibility of crossing and initiate the development of a study of the irradiation of isolated nanoparticles to study relaxation processes following the ionic impact to the work in the interstellar medium.

b. Collaboration – Vacuum and Surface (IJCLAB, B. Mercier, G. Sattonnay, S. Bilgen (PhD student))

In order to continue the studies undertaken in 2019, a UHV (ultra-high vacuum) chamber will be installed on an ANDROMEDE beam line, which will allow characterizing the surface of materials in ultra-vacuum conditions. These studies will be of great interest in the framework of R&D accelerator of IJCLAB, and also CERN.

In addition, as part of the IJCLAB's "Vacuum and Surface" project, many characterization means will be grouped together in D3-D4 after renovation of the buildings (notably those of the PANAMA platform as well as a new scanning electron microscope equipped FEG funded by a SESAME IPNO-IRFU-LAL). The geographic proximity of ANDROMEDE in IGLEX will allow enhanced exchanges and collaborations between the two teams. A photocathode manufacturing and characterization project is being prepared at IJCLAB, for which the use of ANDROMEDE for characterization would prove to be important in the case of equipment for a UHV characterization chamber.

The assembly made up of ANDROMEDE, its low-energy ion columns equipped with ECR source and LMISource, and the "Vacuum and Surface" lab would thus bring together formidable means of characterizing surfaces and materials in a single location and would also make it possible to form a highly attractive characterization platform.

c. Persée Project

The multidisciplinary experiments conducted within the Andromede collaborations, which will continue in 2020, have evidenced that nanoparticle beams constitute a very powerful probe for surface analysis of any type: metallic, organic and biological composites. This is due essentially to the high induced emission yields, whether for secondary atomic, cluster or molecular ions [6].,

whether positively or negatively charged. Microbeams conjugated with electronic or protonic emission induced by the impact of these nanoparticles allow to consider emission microscopy and thus to reach a sub-micrometric localization [3]. On each impact, several hundred ions are emitted and for a given mass, dozens of ions are emitted simultaneously. When associated with a multi-anode detection, such high multiplicy of ions per impact gives rise to unrivaled sensitivity.

Sample analysis are currently carried out with a time-of-flight mass spectrometer. When equipped with an electrostatic reflector, the mass resolutions reach tens of thousands. This is suitable for these first measurements where the molecules and the chemical compositions are known; for the analysis of complex targets the resolution and the precision in mass will not be sufficient. A second evolution of our experimental device is necessary for further studies of biological and exobiological molecules aiming at characterizing, identifying, and locating organic species in a complex matrix.This indeed requires high resolution and mass accuracy as shown by Manale Noun [7,8] for exobiology studies. To have an exact molecular attribution around 200-400 Daltons a resolution higher than 100000 and a precision in mass lower than one ppm is needed. Such performances are now possible with the recent developments in mass spectrometry like the Orbitrap instruments developed by A. Makarov and marketed by Thermo Fisher. Typical resolution of 200,000 can be reached and even 450,000 [9,10] for the latest instruments.

In the framework of the Andromede installation, various developments are studied:

- From the center of the spectrometer chamber, the emitted secondary ions will be deflected by a spherical lens, already installed, towards a time-of-flight arm allowing rapid mass analysis to select the areas of interest on the target. Then, these selected areas will be analyzed by the Orbitrap spectrometer via a transfer-injection line also placed behind the ESA. This ion column was calculated during Elodie Verzeroli's thesis in collaboration with Orsayphysics [11]. The problem with this coupling is that the different types of velocity distributions depending on the ions ejected from the surface, and their complex angular distributions may strongly reduce the rate of transmission.
- A second possibility is the analysis using a mass spectrometer associating an ion mobility cell allowing a separation according to the volume and the conformation of the molecules, a trap with a collision cell which allows to know the molecular structures, and finally a high resolution orthogonal flight time. This structure initially proposed in the ANDROMEDE project following experiments carried out ten years ago [12,13] is now available from Brücker. It is the Time TOF Flex presented at the 67th American Society for Mass Spectrometry Conference (ASMS) which was held June 2-6 in Atlanta. Our objective in collaboration with the Andromede consortium is to couple the EVE chamber with this Brücker instrument presented in Figure 5.

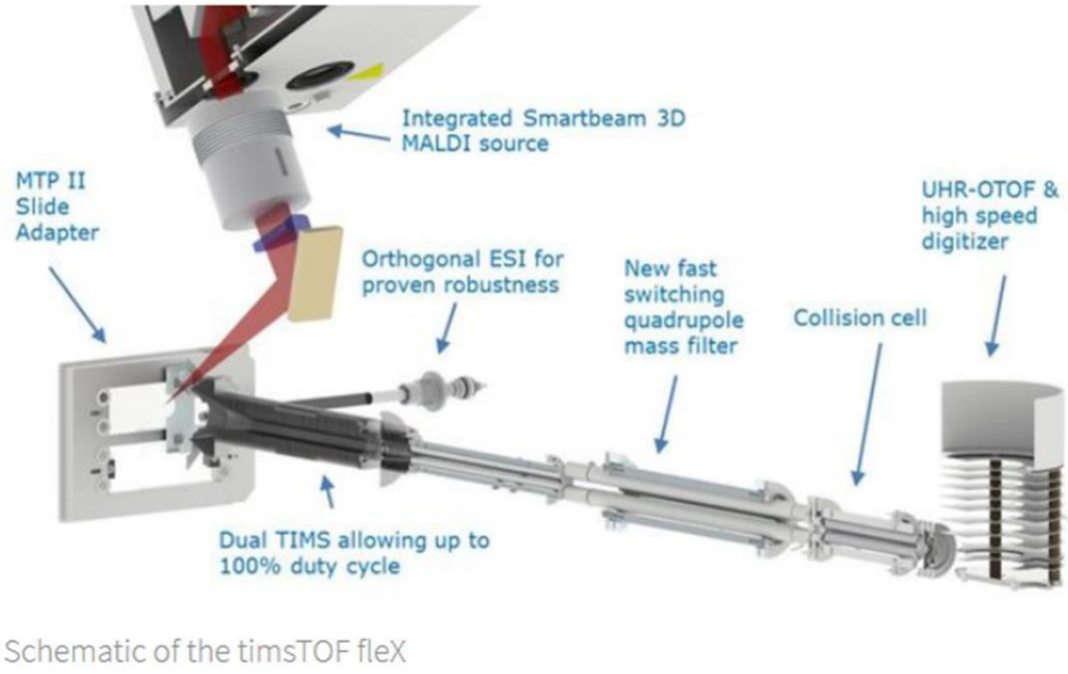


Figure 5 Schéma du timeTOFflex de Brücker

Furthermore, this option offers two conventional ESI and MALDI sources supplementing our analysis of 2D and 3D ion imaging. The combination of the mass spectrometer with the Andromede-EVE instrument just requires an adaptation of the high energy injection line. On the other hand, the use of an ion mobility device allows to get rid of the problem of angular distributions requiring a complex transfer line with a transmission rate less than 100%. This development will be carried out either by a collaborative ANR request or at the level of the AAP EQUIPEX mutualisation.

References

[1] Andromede Project: Surface Analysis and Modification with Probes from Hydrogen to Nano-Particles in the MeV Energy Range, Michael J. Eller, Evelyne Cottereau, Bernard Rasser, Elodie Verzeroli, Benoit Agnus, Gabriel Gaubert, Xavier Donzel, Anne Delobbe, Serge Della-Negra, Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms, 51(décembre 2015) Volume 365, Part A, Pages 367-370

[2] The Pegase project, a new solid surface probe: focussed massive cluster ion beams, S. Della-Negra, J. Arianer, J. Depauw, S.V. Verkhoturov and E.A. Schweikert, Surf.Interface Anal., 2011, 43, 66-69

[3] SIMS instrumentation and methodology for mapping of co-localized molecules M. J. Eller, S. V. Verkhoturov, S. Della-Negra, and E. A. Schweikert, Rev. Sci. Instrum. 84, 103706 (2013)

[4] T. IdBarkach, T. Mahajan, M. Chabot, K. Béroff, N. F. Aguirre, S. DiazTendero, T. Launoy, A. L. Padellec, L. Perrot, M. A. Bonnin, K. C. Le, F. Geslin, N. de Séréville, F. Hammache, A. Jallat, A. Meyer, E. Charon, T. Pino, T. Hamelin, and V. Wakelam. Semiempirical breakdown curves of C2N(+) and C3N(+) molecules; application to products branching ratios predictions of physical and chemical processes involving these adducts. Molecular Astrophysics, 12 :25–32, September 2018.

[5] Emission of Molecular Fragments Synthesized in Hypervelocity Nanoparticle Impacts; C.Guillermier, S.Della-Negra, E.A.Schweikert, A.Dunlop, G.Rizza; *International Journal of Mass Spectrometry 275 (2008) 86-90*

[6] Prompt In Situ Emission of Gold Adducts from Single Impacts of Large Gold Clusters on Organics Solids, C. Guillermier, S. Della Negra , R. D. Rickman, G. J. Hager, E. A. Schweikert, *Int. Journal of Mass Spect.*, *Volume 263*, *Issues 2-3*, 5(*2007), 298-303.*

[7] Manale Noun PhD thesis (08/10/2013) Interaction agrégats-surface. Spectrométrie de masse par temps de vol et application analytique à des études sur des médicaments et sur la météorite Paris

[8] A mineralogical context for the organic matter in the Paris meteorite determined by a multi-technique analysis, Manale Noun, Donia Baklouti, Rosario Brunetto, Thomas Calligaro, Isabelle Ribaud, Ferenc Borondics, Louis Le Sergeant d'Hendecourt , Zélia Dionnet , Bilal Nsouli, Mohamad Roumie and Serge Della-Negra, 2019 MDPI life, 2019 Jun; 9(2): 44.

[9] Makarov, A. Electrostatic axially harmonic orbital trapping: a high-performance technique of mass analysis. Anal. Chem. 72, 1156–1162 (2000).

[10] Hu, Q. et al. The Orbitrap: a new mass spectrometer. J. Mass Spectrom. 40, 430–443 (2005).

[11] E. Verzeroli PhD thesis 21 septembre 2017, Source NAPIS et Spectromètre PSI-TOF dans le projet ANDROMEDE

[12] Agnès Tempez, J.A. Schultz, S. Della-Negra, J. Depauw, D. Jacquet, A. Novikov, Y. Lebeyec, M. Pautrat, M. Caroff, M. Ugarov, H. Bensaoula, M. Gonin, K. Fuhrer, and Amina Woods, Rapid Communications in Mass Spectrometry, 18, 371-376 (2004)
[13] A. Tempez, M. Ugarov, T. Egan, J.A. Schultz, A. Novikov, S. Della-Negra, Y. Lebeyec, M. Pautrat, M. Caroff, V. S. Smentkowski, H-Y. J. Wang, S. N. Jackson, and A.S. Woods. *J. Proteome Res. 4 (2005) 540-545.*

SWOT Analysis

STRENGTHS

- New Platform/low maintenance machine for 5 next years
- Strong multidisciplinary expertises :
  nuclear physics, vacuum and surfaces, materials science, physics and astro-chemistry, biology
- Originality of beams (atomic, aggregates, nanoparticles)
- Unique performance of nanoparticle beams: ion emission efficiency / impact analysis (chemical environment, co-localization, 3D ion imaging, etc.)
- Complementarity of our platform with local, national and international ones

WEAKNESSES

- Strategic Human Resources Plan
  - thesis and post-doc supervision
  - strategy for future project submission
- Operating and maintenance funding
- Chronic dwindling of human and financial resources
- recognition for multidisciplinary Platforms

OPPORTUNITIES

- Unique international research infrastructure
- Local, national and international partnerships
- Lab unification /Technical support IJC Lab
- University Paris-Saclay / interdisciplinary programs focus on training /Meet My Platform
- SATT/ R&D and technology transfer
- Openness of the EMIR federation to the scope of analysis IBA

THREATS

- Sustainability of the platform due to mainly unpaid collaborations
- Change of ASN rules
- Barriers to delivering programs that would no longer be free in the academic community

Annexe 1: Publications

PEGASE / ANDROMEDE

P165 Single Impacts of C_{60} on Solids: Emission of Electrons, Ions and Prospects for Surface Mapping. S. Verkhoturov, M. Eller, R. Rickman, S. Della-Negra, E.A. Schweikert. *J. Phys. Chem. C*, 2010, 114 (12), pp 5637–5644

P166 Ion beam analysis and PD-MS as new analytical tools for quality control of pharmaceuticals: comparative study from Fluphenazine in solid dosage forms" Nsouli, Bilal; Bejjani, Alice; Della-Negra, Serge; Gardon, Alain; Thomas, Jean Paul, Analytical Chemistry, **2010**, *82* (17), pp 7309–7318

P167 Electron Emission from Hypervelocity C_{60} Impacts, Eller M., Verkhoturov S., Della-Negra S., Schweikert E.A., *J. Phys. Chem. C*, **2010**, *114* (40), pp 17191–17196

P169 Statistic of electron and ion emission from single massive cluster impacts, S.V. Verkhoturov, M.J. Eller, S. Della-Negra, R.D. Rickman, J.E. Locklear, E.A. Schweikert, *Surf. Interface Anal.*, 2011, **43**, 49-52.

P170 Photon Emission from massive projectile impacts on solids, F.A. Fernandez-Lima, V.T. Pinnick, S. Della-Negra, E.A. Schweikert. *Surf. Interface Anal.*, 2011, **43**, 53-57.

P172 The Pegase project, a new solid surface probe: focussed massive cluster ion beams S. Della-Negra, J. Arianer, J. Depauw, S.V. Verkhoturov and E.A. Schweikert, *Surf. Interface Anal*.,2011*,* **43**, 66-69.

P173 Real-time Localization of Single C_{60}^+ Impacts with Correlated Secondary Ion Detection, M.J. Eller, S.V. Verkhoturov, S. Della-Negra, R.D. Rickman, E.A. Schweikert, *Surf. Interface Anal.*,2011, **43**, 484-487

P174 Analysis of Native Biological Surfaces Using a 100 kV Massive gold Cluster Source Francisco A. Fernandez-Lima, Jeremy Post, John D. DeBord,Michael J. Eller, Stanislav V. Verkhoturov, Serge Della-Negra, Amina S. Woods and Emile A. Schweikert, *Anal. Chem*. 2011, 83, 8448-8453

P175 Analysis of Fluorescent Proteins with a Nanoparticle Probe, Francisco A. Fernandez-Lima, Michael J. Eller, J. Daniel DeBord, Michaella J. Levy, Stanislav V. Verkhoturov, Serge Della-Negra, and Emile A. Schweikert *J. Phys. Chem. Lett.*, **2012**, *3* (3), pp 337–341

P176 On the Surface Mapping using Individual Cluster Impacts, F. A. Fernandez-Lima, M.J. Eller, J.D. DeBord, S.V. Verkhoturov, S. Della-Negra, E.A. Schweikert, *Nucl. Instr. and Meth. in Phys. Res. B* 273 , 270-273, 2012

P177 Bidirectional Ion Emission from Massive Cluster Impacts on Nanometric Carbon Foils, J.D. DeBord, S. Della-Negra, F. A. Fernandez-Lima, S.V. Verkhoturov, E.A. Schweikert, *J. Phys. Chem. C*, **2012**, *116* (14), pp 8138–8144

P179 Surface characterization of biological nanodomains using NP-ToF-SIMS F. A. Fernandez-Lima, J. D. DeBord, E. A. Schweikert, S. Della-Negra, K. A. Kellersberger and M. Smotherman, *Surface and Interface Analysis,* Volume 45, Issue 1, January 2013, Pages: 294–297

P180 Simultaneous detection and localization of secondary ions and electrons from single large cluster impacts, M. J. Eller, S. V. Verkhoturov, F. A. Fernandez-Lima, J. D. DeBord, E. A. Schweikert and S. Della-Negra, *Surface and Interface Analysis,* Volume 45, Issue 1, January 2013, Pages: 529–531

P181 Characteristics of positive and negative secondary ions emitted from Au3+ and Au400+4 impacts, J. D. DeBord, F. A. Fernandez-Lima, S. V. Verkhoturov, E. A. Schweikert and S. Della-Negra, *Surface and Interface Analysis*, Volume 45, Issue 1, January 2013, Pages: 134–137

P182 Characterization of individual nano-objects with nanoprojectile-SIMS, C.-K. Liang, S. V. Verkhoturov, Y. Bisrat, S. Dikler, J. D. DeBord, F. A. Fernandez-Lima, E. A. Schweikert and S. Della-Negra, *Surface and Interface Analysis*, Volume 45, Issue 1, January 2013, Pages: 329–332,

ANDROMEDE

P171 Massive Clusters: Secondary emission from qkeV to qMeV. New emission processes? New SIMS Probe? S. Della-Negra, J. Depauw, C. Guillermier and E.A. Schweikert, *Surf. Interface Anal*.,2011*,* **43**, 62-65.

P178 Organic residues from ultraviolet irradiation of interstellar ice analogs", P. Modica, P. de Marcellus, D. Baklouti, R. Brunetto, M. Noun, S. Della Negra and L. Le Sergeant d'Hendecourt, *European Conference on Laboratory Astrophysics, EAS Publications Series,* **58** *(2013) 343–347*

P183 On the Characterization of the "Paris" Meteorite Using PIXE, RBS and Micro PIXE, M. Noun, M. Roumie, T. Calligaro, B. Nsouli, R. Brunetto, D. Baklouti, L. d'Hendecourt, S. Della-Negra.
Nucl. Instr.and Meth. in Phys. Res. B 306 (2013) 261-264

P184 SIMS instrumentation and methodology for mapping of co-localized molecules M. J. Eller, S. V. Verkhoturov, S. Della-Negra, and E. A. Schweikert,
Rev. Sci. Instrum. 84, 103706 (2013)

P185 "Hypervelocity nanoparticle impacts on free-standing graphene: A sui generis mode of sputtering,"
Michael J. Eller, Chao-Kai Liang, Serge Della-Negra, Aaron B. Clubb, Hansoo Kim, Amanda E. Young, and Emile A. Schweikert, J. Chem. Phys. **142**, 044308 (2015)

P188 Time-of-flight secondary ion mass spectrometry imaging of biological samples with delayed extraction for high mass and high spatial resolutions
Quentin P. Vanbellingen, Nicolas Elie, Michael J. Eller, Serge Della-Negra, David Touboul andAlain Brunelle ; Rapid Communications in Mass Spectrometry
Volume 29, Issue 13, pages 1187–1195, 15 July 2015

P189 Andromede Project: Surface Analysis and Modification with Probes from Hydrogen to Nano-Particles in the MeV Energy Range,
Michael J. Eller, Evelyne Cottereau, Bernard Rasser, Elodie Verzeroli, Benoit Agnus, Gabriel Gaubert, Xavier Donzel, Anne Delobbe, Serge Della-Negra, Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms, 51(décembre 2015) Volume 365, Part A, Pages 367-370

P190 Mapping Dicorynia guianensis Amsh. Wood Constituents by Submicron Resolution Cluster-TOF-SIMS Imaging
Q.P. Vanbellingen, T. Fu, C. Bich, N. Amusant, D. Stien, S. Della-Negra, D. Touboul, A. Brunelle, J. Mass Spectrom. 51 (2016) 412-423

P191 The collision of a hypervelocity massive projectile with free-standing graphene: Investigation of secondary ion emission and projectile fragmentation
Sheng Geng, Stanislav V. Verkhoturov, Michael J. Eller, Serge Della-Negra, and Emile A. Schweikert, The Journal of Chemical Physics 146, 054305 (2017);

P192 Study of the matrix effect on the PIXE quantification of active pharmaceutical ingredients in different formulations
Alice Bejjani, Manale Noun, Maher Soueidan, Serge Della-Negra, Edmond Abi-Fadel, Mohammad Roumie, Bilal Nsouli
Nuclear Inst. and Methods in Physics Research, B, Volume 406, p. 119-123, 2017,

P193 Fusion Cross Sections of Astrophysics Interest within the Stella Project, S. Courtin, G. Fruet, D. G. Jenkins, M. Heine, D. Montanari, L. G. Morris, G. Lotay, P. H. Regan, O. S. Kirsebom, S. Della Negra, F. Hammache, N. de Sereville, B. Bastin, F. de Oliveira, G. Randisi, C. Stodel, C. Beck, and F. Haas, JPS Conf. Proc. 14, 021001 (2017),

P194 Sub-barrier fusion cross section measurements with STELLA, M. Heine, S. Courtin, G. Fruet, D.G. Jenkins, D. Montanari, P. Adsley, C. Beck, S. Della Negra, P. Dené, F. Haas, F. Hammache, G. Heitz, O.S. Kirsebom, M. Krauth, J. Lesrel, A. Meyer, L. Morris, P.H. Rega, M. Richer, M. Rudigier, N. de Séréville and C. Stodel, EPJ Web of Conf., 165:01029, 2017

P195 Fusion cross section measurements of astrophysical interest for light heavy ions systems within the STELLA project, G. Fruet, S. Courtin, D. G. Jenkins, Marcel Heine, D. Montanari, L. G. Morris, P. Adsley, C. Beck, S. Della Negra, F. Haas1, F. Hammache, O. S. Kirsebom,

A. Meyer, P. H. Regan, M. Rudiger, N. de Séréville and C. Stodel, EPJ Web of Conferences 163, 00018 (2017)

P196 The STELLA Apparatus for Particle-Gamma Coincidence Fusion Measurements with Nanosecond Timing , M. Heine, S. Courtin, G. Fruet, D.G. Jenkins, L. Morris, D. Montanari , M. Rudigier, P. Adsley, D. Curien, S. Della Negra, J. Lesrel, C. Beck, L. Charles, P. Dené, F. Haas, F. Hammache, G. Heitz, M. Krauth, A. Meyer, Zs. Podolyák, P.H. Regan, M. Richer, N. De Séréville, C. Stodel. Nucl.Instrum.Meth.A, 2018, 903, pp.1-7.

P197 Tandem MS imaging and in situ characterization of bioactive wood metabolites in Amazonian tree species Sextonia rubra
Fu, Tingting; Touboul, David; Della-Negra, Serge; Houël, Emeline; Amusant, Nadine; Duplais, Christophe; Fisher, Gregory; Brunelle, Alain.
Analytical Chemistry, 2018, 90 (12) , 7535-7543

P198 Internal energy distribution of secondary ions under argon and bismuth cluster bombardments: 'soft' versus 'hard' desorption-ionization process.
Tingting Fu, Serge Della Negra, David Touboul, Alain Brunelle, J. Am. Soc. Mass Spectrom. 30 (2019) 321-328

P199 Biosynthetic investigation of □-lactones in *Sextonia rubra* wood using *in situ* TOF-SIMS MS/MS imaging to localize and characterize biosynthetic intermediates
Tingting Fu, Emeline Houël, Nadine Amusant, David Touboul, Grégory Genta-Jouve, Serge Della-Negra, Gregory L. Fisher, Alain Brunelle, Christophe Duplais
Scientific Reports-Nature **9**, Article number: 1928 (2019)

P200 Breakdown curves of CH(+) 2 , CH(+) 3 , and CH(+) 4 molecules I. Construction and application to electron collisions and UV photodissociation T. IdBarkach, M. Chabot, K. Béroff, S. Della Negra, J. Lesrel, F. Geslin, A. Le Padellec, T. Mahajan, and S. Díaz-Tendero; A&A 628, A75 (2019)1-14

Annexe 2 : présentations dans les conférences

Communications PEGASE/ANDROMEDE :

- SIMS XVII Conference, September 13-18, 2009, Toronto – ON, Canada
  Statistics of Electron and Ion Emission from Single Massive Cluster Impacts
  S. V. Verkhoturov , S. Della-Negra , M.J. Eller , R.D. Rickman , E.A. Schweikert
  Real-time localization of single C_{60} impacts with correlated secondary ion detection
  M.J. Eller , S.V. Verkhoturov , S. Della-Negra , R.D. Rickman , and E.A. Schweikert
  Photon emission from massive projectile impacts on solids
  F. A. Fernandez-Lima, V. T. Pinnick, S. Della-Negra, and E. A. Schweikert
  Massive Clusters : Secondary emission from qkeV to qMeV. New emission processes? New SIMS Probe?
  S. Della-Negra, J. Depauw, C. Guillermier and E.A. Schweikert
  The Pegase project A new solid surface probe: focussed massive cluster ion beams.
  S. Della-Negra[1], J. Arianer[1], J. Depauw[1], S.V. Verkhoturov[2] and E.A. Schweikert

- 58th ASMS Conference on Mass Spectrometry conference, May 22 - 23, 2010, Salt Lake City, Utah
  Surface Mapping using Individual Cluster Impacts Francisco Alberto Fernandez Lima[1]; Michael J. Eller[1]; Stanislav V. Verkhoturov[1]; John D. DeBord[1]; Serge Della-Negra[2]; Emile A. Schweikert[1]

- 22 th annual Workshop on SIMS, May 17-21 2010, Norfolk, VA, USA
  Surface Mapping with Cluster-SIMS, S.V. Verkhoturov[a], M.J. Eller[a], S. Della-Negra[b], F.A. Fernandez-Lima[a], E.A. Schweikert

- Desorption2010, Seillac, May 31-June 3, France
  - **Size Dependent Electron Emission from C60 Impacts** M. J. Ellera, S. V. Verkhoturova, F.A.Fernandez-Lima, S. Della-Negrab and E. A. Schweikert
    - **On the Photon, Electron and Secondary Ion Emission under Cluster Projectile Bombardment,** Francisco A. Fernandez-Lima, John D. DeBorda, M. J. Ellera, S. V. Verkhoturova, Serge Della-Negrab and Emile A. Schweikert
    - **Secondary Ion Emission from Nano-Volumes using Massive Gold Projectiles in Transmission Mode,** John D. DeBord*, Francisco A. Fernandez-Lima*,Serge Della-Negra†, Stanislav V. Verkhoturov*, and Emile A. Schweikert*

- 20th International Conference on Ion Beam Analysis, Plaza Itapema Resort & Spa,Itapema, SC-Brazil,10-15 April, 2011
  - **Surface Mapping using Individual Cluster Impacts,**F.A. Fernandez-Lima, M.J. Eller, J.D. DeBord, S.V. Verkhoturov, S. Della-Negra , and E.A. Schweikert

- 23rd Annual Workshop on SIMS. USA Baltimore, May 17-20, 2011
  - **Nanoprojectile Impacts on Nanometric Carbon Foils: Impact and Exit Side Ion Emission** J. DeBord*, F. Fernandez-Lima, S. Della-Negra, S. Verkhoturov, E. Schweikert
  - **Enhanced Molecular Ion emission using a 100kV Massive Gold Cluster source from native biological surfaces** F.A. Fernandez-Lima*, J.D. DeBord, M.J. Eller, J.D. S.V. Verkhoturov, S. Della-Negra, E. A. Schweikert
  - **Surface characterization of biological nanodomains using NP-ToF-SIMS** F. A. Fernandez-Lima, J. D. DeBord, E. A. Schweikert, S. Della-Negra, K. A. Kellersberger and M. Smotherman,
  - **Simultaneous detection and localization of secondary ions and electrons from single large cluster impacts** M. J. Eller, S. V. Verkhoturov, F. A. Fernandez-Lima, J. D. DeBord, E. A. Schweikert and S. Della-Negra
  - **Characteristics of positive and negative secondary ions emitted from Au3+ and Au400+4 impacts**, J. D. DeBord, F. A. Fernandez-Lima, S. V. Verkhoturov, E. A. Schweikert and S. Della-Negra,
  - **Characterization of individual nano-objects with nanoprojectile-SIMS**, C.-K. Liang, S. V. Verkhoturov, Y. Bisrat, S. Dikler, J. D. DeBord, F. A. Fernandez-Lima, E. A. Schweikert and S. Della-Negra,

Communications ANDROMEDE

SIMS XVII Conference, September 13-18, 2009, Toronto – ON, Canada

Massive Clusters : Secondary emission from qkeV to qMeV. New emission processes? New SIMS Probe?

S. Della-Negra, J. Depauw, C. Guillermier and E.A. Schweikert

GDR COMBAVIR, le 13 Décembre à l'Institut Pasteur

« ORION, PEGASE et ANDROMEDE ; dispositifs présents et futurs pour l'analyse de la matière biologique»

S. Della-Negra

Monochromatic ion and electron beams: New sources and Applications, Orsay, February 10th, 2011 (dans le cadre du projet GULSTREAM soutenu par le triangle de la Physique)

Nano-particle beams

S.Della-Negra, Invited Talk

18th International Conference on Secondary Ion Mass Spectrometry, SIMSXVIII, Riva del Garda, September 18-23, 2011, Italy

Andromeda and END-MS, New generation of Surface Analysis Instrument
S. Della-Negra[1], V. Huc[2], B. Rasser[3] and E.A.S. Schweikert

Joint IAEA-SPIRIT-Japan Technical Meeting on"Development and Utilization of MeV-SIMS", 21 – 25 May 2012, Dubrovnik, Croatia

Cluster ion beam sputtering and Secondary ion emission using experimental techniques with a wide range of energies and cluster sizes.
S. Della-Negra, Invited talk

Desorption 2012, June 3 - 7, 2012, Rauischholzhausen, Germany

Paris meteorite analysis by cluster SIMS imaging and micro-PIXE M. Noun[1,2], , M. Pautrat[1], B. Nsouli[2], M. Roumie[2], T. Calligaro[3], D. Baklouti[4], R. Brunetto[4],S. Merouane[4], L. d'Hendecourt[4] and S. Della Negra[1]

European Planetary Science Congress 2012, IFEMA-Feria de Madrid, 23 – 28 September 2012, Madrid, Spain

Micro-IR reflectance spectra of the Paris carbonaceous chondrite coupled to ToF-SIMS and micro-Raman spectroscopy D. Baklouti, R. Brunetto, M. Noun, S. Della Negra, M. Pautrat, F. Jamme, C. Sandt, P. Dumas, B. Nsouli, M. Roumie, S. Merouane, L. d'Hendecourt, and E. Dartois

SIMS Europe, Muenster (Germany)9th - 11th September 2012 :

On the secondary ion emission from a mixture of active pharmaceutical ingredients under keV-cluster bombardment, M. Noun, B. Nsouli, A. Bejjani, J. Depauw, M. Pautrat and S. Della Negra.

XVIIIèmes rencontres de la société française de spectrométrie de masse SFSM 2013, 8 avril 13 avril 2013, Pau (France):

Quantification of the active pharmaceutical ingredients using cluster Secondary Ion Mass Spectrometry; M. Noun, B. Nsouli and S. Della Negra.

The 2nd Tandem/ALTO Workshop, IPN Orsay the 14th and 15th of May 2013

From Orion to Andromeda flying with Pegasus S. Della-Negra, Invited Talk

XVIIIèmes rencontres de la société française de spectrométrie de masse SFSM 2013, 8 avril 13 avril 2013, Pau (France):

Quantification of the active pharmaceutical ingredients using cluster Secondary Ion Mass Spectrometry; M. Noun, B. Nsouli and S. Della Negra.

25th Annual Workshop on SIMS, May 13 - 17, 2013, Annapolis MD 2140, USA

Characterization of Gold LMIS and Integration into Andromede Project Michael J. Eller[a,*], Bernard Rasser[b], Nimer Wehbe[c], Manale Noun[a], Patrick Philipp[c], Evelyne Cottereau[a], Serge Della-Negra[a]

SIMS Methodology for Individual Nanoparticles Chao-Kai Liang[1], M.J. Eller[1,2], S.V. Verkhoturov[1], S. Della-Negra[2], E.A. Schweikert[1]

61st ASMS Conference, June 9 - 13, 2013 in Minneapolis, USA

Cluster Ion Imaging of the "Paris" Meteorite M. Noun[1,2], B. Nsouli[2], D. Baklouti[3], R. Brunetto[3], S. Merouane[3], L. d'Hendecourt[3], and S. Della-Negra[1]

Particle – surface interactions: from surface analysis to materials processing" (PASI 2013) Luxembourg City, June 3rd to 5th, 2013

Characterization of novel Gold LMIS delivering projectiles up to nanoparticle sizes for organic SIMS applications

Michael J. Eller[a,*], Bernard Rasser[b], Nimer Wehbe[c], Manale Noun[a], Patrick Philipp[c], Evelyne Cottereau[a], Serge Della-Negra[a]

19th International Vacuum Congress *IVC-19* - September 9-13, Paris 2013

Paris" meteorite analysis using cluster and particle impacts

M. Noun, D. Baklouti, R. Brunetto, S. Merouane, L. D'hendecourt, B. Nsouli , M. Roumie, F. Jamme, C. Sandt , P.Dumas, T. Calligaro, S. Della-Negra

Development of Ion Mapping for SIMS with an EEM

Michael J. Eller, Stanislov V. Verkhoturov, Serge Della-Negra, Emile A. Schweikert

Desorption 2014, Hilton Bonaventure Hotel, Montreal(Canada), April 14-16, 2014

Andromede Project Present Status and Outlook

Michael J. Eller[1], Bernard Rasser[2], Anne Delobbe[2], Elodie Verzeroli[2], Arnaud Houel[2], Evelyne Cottereau[1], Serge Della-Negra[1]

Paris meteorite elemental and structural imaging analysis.

M. Noun[1, 2,*], B. Nsouli[2], T. Calligaro[3], D. Baklouti[4], R. Brunetto[4], L. d'Hendecourt[4] and S. Della Negra[1].

9TH INTERNATIONAL CONFERENCE ON CHARGED PARTICLE OPTICS, AUG 31–SEP 5, 2014 Hotel Continental, Brno, Czech Republic

CO179 **Development of a compact high performance mass spectrometer for combined TEM-SIMS nano-analytics**

M. S. Verruno, D. Dowsett, T. Wirtz, S. Della Negra

CO180 **First design steps of a high-brightness electro-impact ion source for nano-applications**

O. De Castro, D. Dowsett, T. Wirtz, S. Della Negra

16th International Conference on Ion Sources, Brookhaven National Laboratory, from Sunday August 23 to Friday August 28, 2015 at the Marriott Marquis Hotel, Manhattan, New York, USA

DESIGN STEPS TOWARDS A HIGH BRIGHTNESS ELECTRON IMPACT ION SOURCE

Olivier DE CASTRO, David Dowsett, Tom Wirtz, Serge Della Negra

SIMSXX, 20th INTERNATIONAL CONFERENCE ON SECONDARY ION MASS SPECTROMETRY in Seattle, Washington, USA, from Sept. 13-18, 2015.

MeV Particles, Huge Impact, Soft Desorption.

S. Della-Negra, exposé invite

Workshop Sur la physique des accélérateurs à Basse Energie, 09-10 Avril 2016, Université des Sciences et de la Technologie Houari Boumediene Alger (Algérie).

Des ions atomiques aux nano-particules de haute énergie pour sonder la surface et obtenir une image ionique.

S. Della Negra, Exposé Invité

SIMS EUROPE 2016, Muenster(Germany) 18 septembre 21 septembre

Localization of bioactive metabolites in durable tropical tree Sextonia rubra Lauraceae) with argon and bismuth cluster dual beam depth profiling and imaging

Tingting Fu, David Touboul, Serge Della-Negra, Emeline Houël, Nadine Amusant, Christophe Duplais,Alain Brunelle

Francophone TOF-SIMS Users' meeting, Fuveau (France), March 2017.

Internal energy distribution of secondary ions produced under argon and bismuth cluster bombardments.
T. Fu, D. Touboul, S. Della-Negra, A. Brunelle.

Pittcon 2017, March 5 – 9 at McCormick Place in Chicago, Illinois, USA.

TOF-secondary mass spectrometry imaging and 13C natural isotopic abundance measurement using NMR spectroscopy to investigate the biosynthetic pathways of bioactive metabolites in the Amazonian tree species Sextonia rubra (Lauraceae)
Tingting Fu, Nadine Amusant, Emeline Hoüel, David Touboul, Serge Della-Negra, Richard Robins, Gérald Rémaud, Alain Brunelle, Christophe Duplais

SIMSXXI,21st INTERNATIONAL CONFERENCE ON SECONDARY ION MASS SPECTROMETRY in Krakow, Poland, September 10-15 2017

Andromede, a new tool to produce and analyze nano-objects
S. Della Negra, J. Lesrel, M. Eller, E.A. Schweikert, D. Baklouti, R. Brunetto, M. Caroff, M. Chabot, S. Courtin, V. Huc, E. Verzeroli.

Internal energy distribution of secondary ions under argon and bismuth cluster bombardments
Tingting Fu, David Touboul, Serge Della-Negra, Alain Brunelle

Elucidation of natural product Bio-Synthesis in Amazonia, Sextonia rubra via 100 nm scale TOF SIM- tandem MS Imaging
G. Fisher, T. Fu, D. Touboul, A. Brunelle, S. Della Negra, N. Amusant, E. Houet, C. Duplais

WORKSHOP ON ALTO PROSPECTS, ORSAY, February 5-7, 2018

From ALTO to Andromède
S. Della-Negra Invited talk

SYMPOSIUM OF NORTH EASTERN ACCELERATOR PERSONNEL, 2018, MADISON, WISCONSIN (USA) September 23-27

Andromede, proton to nanoparticle MeV beams
S. Della Negra, J. Lesrel, I. Ribaud
Invited talk

SMAP 2019, Strasbourg (France) 16-19 septembre 2019

Andromede: MeV-Nanoparticle-SIMS for surface analysis
Lai Thanh-Loan [1], Della Negra Serge [1], Jacquet Dominique [1], Lesrel Jean [1], Ribaud Isabelle [1], Bilgen Suheyla [2], Mercier Bruno [2], Sattonnay Gael [2], Baklouti Donia [3], Arribard Yann [3], Augusto Luis [4], Chaby Richard [4], Tissieres Pierre [4], Eller Michael John [5], Verkhoturov Stanislav V. [5], Schweikert Emile A.

IBA2019 Antibes (France) 13-18 Octobre 2019

Dynamic Pressure in the LHC, TOF-SIMS USING A GOLD NANOPARTICLE BEAM TO ANALYSE COPPER TECHNICAL SURFACES FOR ULTRA HIGH VACUUM APPLICATION
S. Bilgen, G. Sattonnay B. Mercier, C. Bruni, V. Baglin S. Della Negra, I. Ribaud, D. Jacquet, L. Lai

Andromede: a multi-purpose innovative facility for surface analysis by MeV nanoparticle impacts

T.L. Lai, S.Della Negra, D. Jacquet, J. Lesrel, I. Ribaud, L. Augusto, R. Chaby, P. Tiessieres, M. Eller, D. Verkhoturov, EA Schweikert, D. Baklouti , R. Brunetto, IAS

SIMSXXII Kyoto (Japan) 20-25 Octobre 2019

Andromede, Innovative Multi-purpose Facility for Surface Analysis

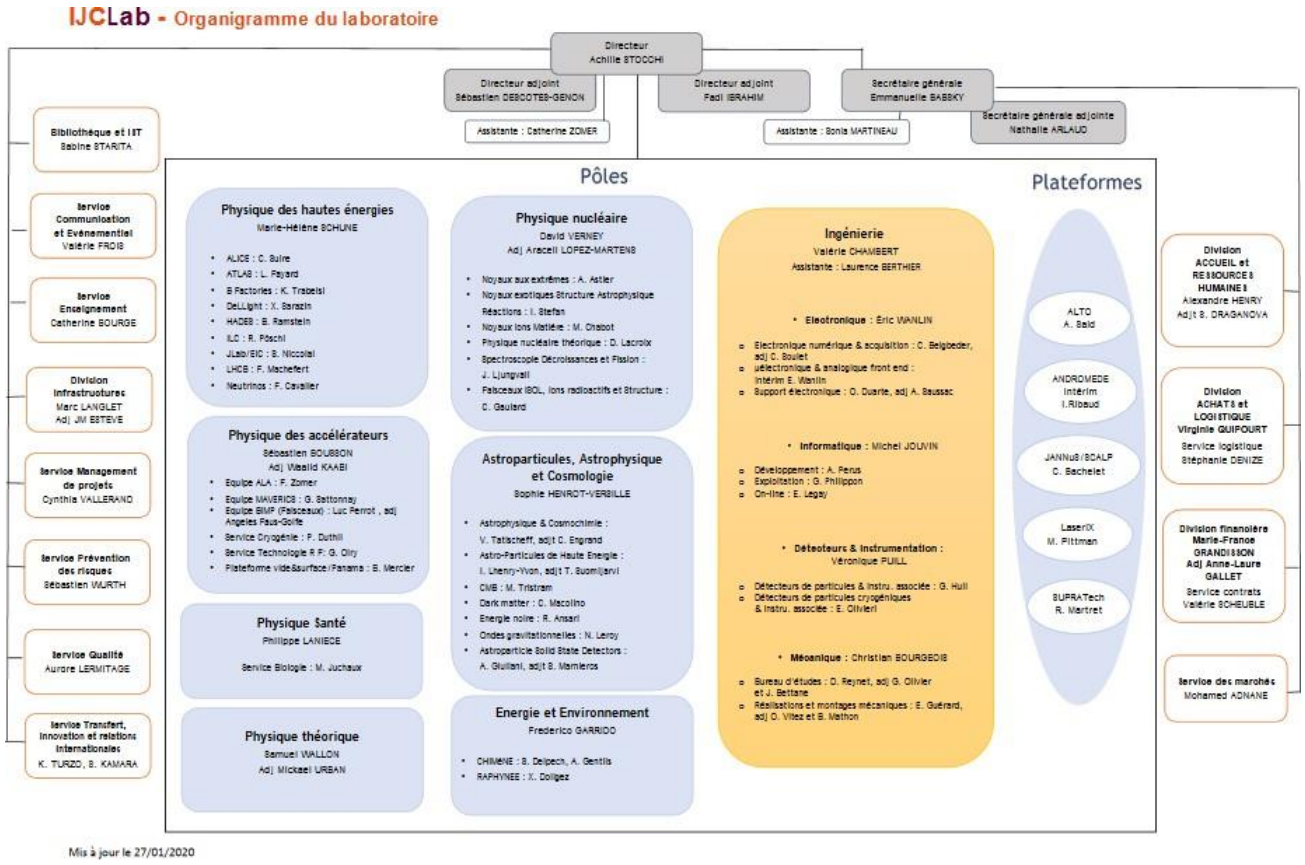
S. Della Negra[1], D. Jacquet[1], T.L. Lai[1], J. Lesrel[1], I. Ribaud[1], S. Bilgen[2], B. Mercier[2], G. Sattonnay[2], D. Baklouti[3], R. Brunetto[3], L. Augusto[4], R. Chaby[4], P. Tissieres[4], M. J. Eller[5], S.V. Verkhoturov[5], E.A. Schweikert[5]

Annexe 3 : EQUIPEX mid Term 2017 audit report

ANDROMEDE.pdf

Annexe 4 : IJC Lab organization chart

https://intranet.ijclab.in2p3.fr/les-organigrammes/



Andromeda position in scientific and platform networks

IN2P3

Andromede is an IN2P3 labeled platform which strengthens and complements the technical expertise of the IN2P3 laboratories at the host laboratory level, regionally, nationally and internationally. The platform is visible on the IN2P3 Technews website, a showcase of technical expertise from IN2P3 laboratories. The platform staff also participate in the activities of the IN2P3 expertise network, such as the experimental biology network (in progress) and the quality management network.

http://cnrs-in2p3-tech-news.in2p3.fr/plateformes/

P2Io

P2IO defines itself as the network of all laboratories in Paris region involved in physics of the infinitely small to the infinitely large. A completer

http://www.labex-p2io.fr/Phocea/Vie_des_labos/Ast/index.php?aff=technique

EMIR&A (in progress)

EMIR&A is a French National network of accelerators for irradiation and analysis of molecules and materials. In 2019, the EMIR becomes EMIR&A and it now covers two separate but complementary fields :

- Irradiation and radiolysis of molecules and materials in the continuation of EMIR ;
- Ion beam analysis of materials (IBA).

The Andromeda platform will be able to offer experiments on the EMIR installations that will take advantage of the original capacities of IBA and not available in other installations.

Annexe 5 : delivered beam time since 2016