NATIONAL CENTRE FOR SCIENTIFIC RESEARCH "DEMOKRITOS"
INSTITUTE OF NUCLEAR & PARTICLE PHYSICS

ACTIVITIES REPORT
2015-2017

INSTITUTE OF NUCLEAR AND PARTICLE PHYSICS

NATIONAL CENTER FOR SCIENTIFIC RESEARCH DEMOKRITOS

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frontpage photo
The main building of the Institute of Nuclear & Particle Physics, where the Tandem Accelarator, the Nuclear Physics and part of the Experimental High Energy and Astroparticle Physics laboratory facilities are hosted, designed by the architect A. N. Tombazis in the late sixties.

EDITORS:

Dr. G. Daskalakis
Ms. G. Kareli
Dr. K. Papadopoulos

November 2018

Institute of Nuclear & Particle Physics,
NCSR "Demokritos"
Aghia Paraskevi, 15310, Athens, Greece
http://www.inp.demokritos.gr

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Overview

The Institute of Nuclear and Particle Physics (INPP), at NCSR Demokritos, has as its mission the experimental and theoretical research, scientific excellence and innovation in High-Energy Physics, Nuclear Physics and Astro-Particle Physics as well as their applications in line with the National Research and Innovation Strategy for Smart Specialisation.

The experimental and theoretical research in High Energy Physics focuses on the study of elementary particles and their interactions. INPP participates in the CMS and ATLAS experiments of the LHC at CERN. The Detector Instrumentation Laboratory (DIL) and the Data Acquisition, Monitoring and Analysis Laboratory (DAMA) of INPP, develop innovative detector technologies and instrumentation along with applications in science and innovation.

Nuclear Physics research focuses on Nuclear Structure, Nuclear Reactions, Nuclear Astrophysics and the study of interactions of X-rays with matter. The INPP hosts a 5.5. MV Tandem accelerator, a unique research infrastructure in Greece that is open to external users from Greece and abroad. The Tandem accelerator laboratory is an interdisciplinary open-access research infrastructure with innovative applications covering the fields of cultural heritage, environment, energy, human health and the development and testing of advanced materials and detectors. The XRF laboratory focuses on cultural heritage, environmental monitoring and biomedicine and offers technology transfer and on-site analytical services to museums, archaeological sites and other institutions.

The Astro-Particle Physics group participates in the development, deployment, data acquisition and data analysis of the kilometer cube underwater neutrino telescope in the Mediterranean, KM3NeT. The INPP hosts the Laboratory of Assembly, Testing and Calibration of the Digital Optical Modules, the basic units of the KM3NeT telescope. The INPP supports also the Deep-Sea Technology and Astro-Particle Physics Research Infrastructure in South-West Peloponnese (Kalamata, Pylos, Methoni).

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Ms. G.Kareli, Secretary INPP
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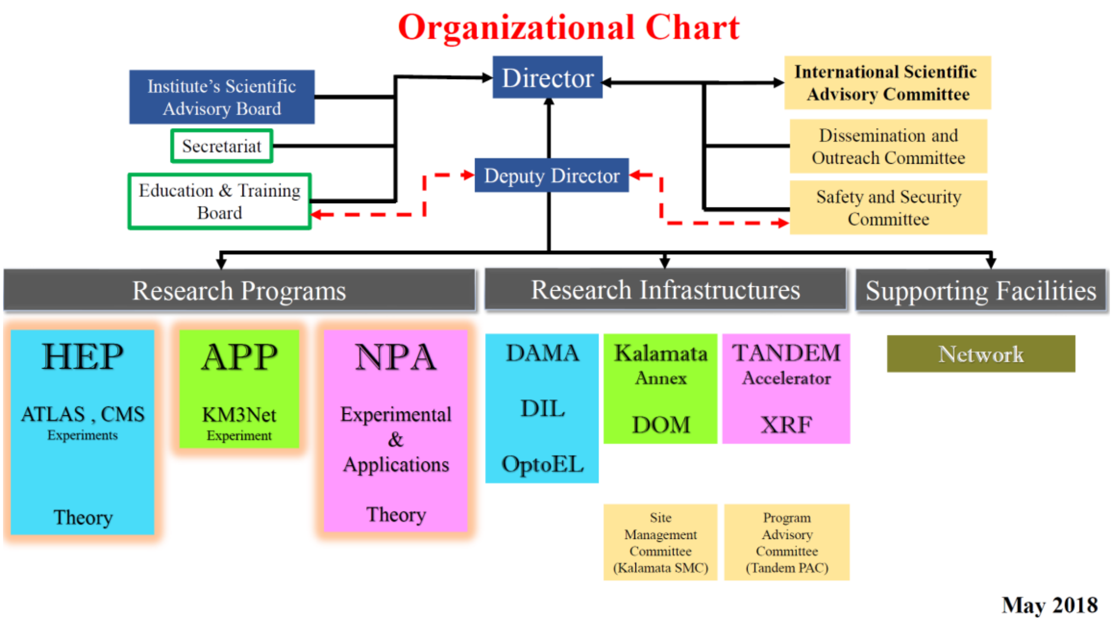
Web-site: www.inp.demokritos.gr

The presentations in the last annual meeting of INPP (15-16/11/2017) can be found here: https://indico.cern.ch/event/680759/

INSTITUTE OF NUCLEAR PHYSICS

Organizational Chart



Director:	Dr. S. Harissopoulos (15/4/2014-25/9/2017, resigned)
Deputy Director:	Dr. G. Fanourakis (18/2/2014-17/2/2015) Dr. C. Papadopoulos (20/9/2017-today, 9/11/2017-today, Acting Director)
Administration:	G. Kareli, Secretary E. Simantirakis, Management

Institute Scientific Advisory Board (Ε.Σ.Ι.)

29/12/2015-16/6/2016	17/6/2016-26/6/2018	27/6/2018-today
- S. Harissopoulos (director) - M. Axenides - G. Fanourakis - C. Markou - G. Stavropoulos	- G. Fanourakis (Chairman) - G. Daskalakis - D. Loukas - C. Papadopoulos, repl. by C. Markou 9/11/2017, repl. by A. Lagoyiannis 28/2/2018 - G. Stavropoulos	- T. Geralis (Chairman) - G. Daskalakis - A. Karydas - G. Savvidy - G. Stavropoulos

International Scientific Advisory Committee

Prof. Nicolas ALAMANOS,
Prof. Ioannis BAKAS,
Prof. Angela BRACCO,
Prof. Muhsin HARAKEH,
Prof. Per Olaf HULTH,
Prof. Yannis KARYOTAKIS,
Prof. Karlheinz LANGANKE,
Prof. Christos TOURAMANIS

Scientists in charge

High Energy Physics
Dr. G. Fanourakis: DAMA & Education Office NCSR-D
Dr. T. Geralis: HEP-ATLAS
Dr. D. Loukas: HEP-CMS & DIL
Dr. G. Savvidy: HEP-Theory

Nuclear Physics & Applications
Dr. D. Bonatsos: Nuclear Structure Theory
Dr. S. Harissopoulos: NPA-Experimental Nuclear Physics & Applications - Tandem
Dr. A. Karydas: XRF Laboratory & Applications

Astroparticle Physics
Dr. C. Markou: APP-KM3NeT & Education INPP

PERSONNEL

	Researchers	phone	Division	E-mail
1	Dr. Georgios ANAGNOSTOU	3514	Exp. High-Energy Physics	anagnog@inp.demokritos.gr
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4	Dr. Dionysios BONATSOS	3519	Theoretical Nuclear Physics	bonat@inp.demokritos.gr
5	Dr. Georgios DASKALAKIS	3535	Exp. High-Energy Physics	daskalakis@inp.demokritos.gr
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11	Dr. Aristotelis KYRIAKIS	3515	Exp. High-Energy Physics	kyriakis@inp.demokritos.gr
12	Dr. Anastasios LAGOYANNIS	3597	Exp. Nuclear Physics	lagoya@inp.demokritos.gr
13	Dr. Dimitrios LOUKAS	3415	Exp. High-Energy Physics	loukas@inp.demokritos.gr
14	Dr. Christos MARKOU	3409	Astroparticle Physics	cmarkou@inp.demokritos.gr
15	Dr. Konstantinos PAPADOPOULOS	3438	Theoretical Particle Physics	cgppdo@inp.demokritos.gr
16	Dr. Petros RAPIDIS (resigned 31/12/2015)		Astroparticle Physics	
17	Prof. Georgios SAVVIDES	3968	Theoretical Particle Physics	savvidy@inp.demokritos.gr
18	Dr. Georgios STAVROPOULOS	3476	Exp.High-Energy & Astroparticle Physics	stavrop@inp.demokritos.gr
19	Dr. Ekaterini TZAMARIUDAKI	3531	Astroparticle Physics	katerina@inp.demokritos.gr

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1	Sophia BAKOU	27210 - 28903	Προσωπικό καθαριότητας	bakou@inp.demokritos.gr

Administration

1	Emmanouel SIMANTIRAKIS	3513	Τεχνικός	msiman@inp.demokritos.gr

Secretariat

1	Georgia KARELI	3512	Διοικητικός	gkarel@inp.demokritos.gr

PERSONNEL
(non-permanent)

Α/Α	ΕΠΩΝΥΜΟ	ΟΝΟΜΑ	ΕΡΓΟ	ΕΠΙΣΤ. ΥΠΕΘΥΝΟΣ	ΕΝΑΡΞΗ	ΛΗΞΗ	ΠΑΡΑΤΑΣΗ ΕΩΣ	ΘΕΣΗ	ΕΙΔΟΣ ΣΥΜΒΑΣΗΣ	
1	ΦΙΛΙΠΠΙΔΗΣ	ΧΡΗΣΤΟΣ	11701	Χ. ΜΑΡΚΟΥ	1/1/13	12/31/14	1/1-30/6/2015	ΤΕΧΝΙΚΟΣ	ΑΝΑΘΕΣΗ ΕΡΓΟΥ	
			11784	Χ. ΜΑΡΚΟΥ	4/20/15	19/10/15			ΑΝΑΘΕΣΗ ΕΡΓΟΥ	
2	ΚΑΖΑΣ	ΙΩΑΝΝΗΣ	11784	Δ. ΛΟΥΚΑΣ	7/2/13	7/1/15	20/10 - 31/12/2015	ΤΕΧΝΙΚΟΣ	ΑΝΑΘΕΣΗ ΕΡΓΟΥ	
			11928	SIEMENS	6/27/16	9/26/16			ΑΝΑΘΕΣΗ ΕΡΓΟΥ	
			12164	ΛΟΥΚΑΣ	1/12/18	7/11/18			ΑΝΑΘΕΣΗ ΕΡΓΟΥ	
3	ΦΙΛΙΟΣ	ΓΕΩΡΓΙΟΣ	11784	ΣΑΒΒΙΔΗΣ	7/3/13	7/2/15		Μεταπτυχ/κός Φοιτητής	ΑΝΑΘΕΣΗ ΕΡΓΟΥ	
4	ΛΙΝΑΡΔΟΠΟΥΛΟΣ	ΓΕΩΡΓΙΟΣ	11784	ΑΞΕΝΙΔΗΣ	7/5/13	7/4/15	20/10 - 31/12/2015	PhD	ΑΝΑΘΕΣΗ ΕΡΓΟΥ	
5	ΑΝΤΩΝΑΚΗ	ΑΡΙΑΔΝΗ	11784	Θ. ΓΕΡΑΛΗΣ	7/3/13	7/2/15	20/10 - 31/12/2015	PhD	ΑΝΑΘΕΣΗ ΕΡΓΟΥ	
6	ΚΟΝΙΤΟΠΟΥΛΟΣ	ΣΠΥΡΙΔΩΝ	11784	Γ. ΣΑΒΒΙΔΗΣ	7/3/13	7/2/15	20/10 - 31/12/2015	PhD	ΑΝΑΘΕΣΗ ΕΡΓΟΥ	
7	ΔΙΑΚΟΝΙΔΗΣ	ΘΕΟΔΩΡΟΣ	11784	Γ. ΔΑΣΚΑΛΑΚΗΣ	7/3/13	7/2/15		PhD	ΑΝΑΘΕΣΗ ΕΡΓΟΥ	
8	ΜΑΝΩΛΟΠΟΥΛΟΣ	ΚΩΝ/ΝΟΣ	11784	Α. ΜΠΕΛΙΑΣ	9/1/13	8/31/15	20/10 - 31/12/2015	PhD	ΑΝΑΘΕΣΗ ΕΡΓΟΥ	
9	ΑΞΙΩΤΗΣ	ΜΙΧΑΛΗΣ	11784	Σ. ΧΑΡΙΣΟΠΟΥΛΟΣ	10/1/13	9/30/15	1/10 - 31/12/2015	PhD	ΑΝΑΘΕΣΗ ΕΡΓΟΥ	
			11928		4/18/16	1/31/17			ΑΝΑΘΕΣΗ ΕΡΓΟΥ	SIEMENS
10	ΦΩΤΕΙΝΟΥ	ΒΑΡΒΑΡΑ	11784	Σ. ΧΑΡΙΣΟΠΟΥΛΟΣ	10/1/14	9/30/15	1/10 - 31/12/2015	PhD	ΑΝΑΘΕΣΗ ΕΡΓΟΥ	
			11928		4/18/16	8/31/16			ΑΝΑΘΕΣΗ ΕΡΓΟΥ	SIEMENS
11	ΑΝΔΡΙΑΝΗΣ	ΜΙΛΤΙΑΔΗΣ	11784	Σ. ΧΑΡΙΣΟΠΟΥΛΟΣ	10/1/13	9/30/15	1/10 - 31/12/2015	ΤΕΧΝΙΚΟΣ	ΑΝΑΘΕΣΗ ΕΡΓΟΥ	
			11928		4/18/16	1/31/17			ΑΝΑΘΕΣΗ ΕΡΓΟΥ	SIEMENS
			11551	Α. ΛΑΓΟΓΙΑΝΝΗΣ	9/1/17	2/28/18			ΕΡΓΑΣΙΑΣ	
12	ΕΛΜΑΛΗΣ	ΕΛΕΥΘΕΡΙΟΣ	11784	Γ. ΔΑΣΚΑΛΑΚΗΣ	9/20/13	9/19/15	20/10 - 31/12/2015	Μεταπτυχ/κός Φοιτητής	ΑΝΑΘΕΣΗ ΕΡΓΟΥ	
13	ΚΑΝΤΑΡΕΛΟΥ	ΒΑΣΙΛΙΚΗ	11784	Α. ΚΑΡΥΔΑΣ	10/1/13	9/30/15	1/10 - 31/12/2015	PhD - ΤΕΧΝΙΚΟΣ	ΑΝΑΘΕΣΗ ΕΡΓΟΥ	
			10231		12/7/16	3/6/17			ΑΝΑΘΕΣΗ ΕΡΓΟΥ	
14	ΚΑΛΑΜΑΡΗΣ	ΑΘΑΝΑΣΙΟΣ	11784	Θ. ΓΕΡΑΛΗΣ	9/16/13	9/15/15	20/10 - 31/12/2015	Μεταπτυχ/κός Φοιτητής	ΑΝΑΘΕΣΗ ΕΡΓΟΥ	
15	ΒΑΣΣΟΥ	ΧΡΥΣΟΥΛΑ	11784	Γ. ΦΑΝΟΥΡΑΚΗΣ	10/30/13	10/30/15	1/11 - 31/12/2015	ΤΕΧΝΙΚΟΣ	ΑΝΑΘΕΣΗ ΕΡΓΟΥ	
16	ΚΟΥΡΗΣ	ΗΛΙΑΣ	11784	Γ. ΦΑΝΟΥΡΑΚΗΣ	10/15/13	10/15/15		Μεταπτυχ/κός Φοιτητής	ΑΝΑΘΕΣΗ ΕΡΓΟΥ	

17	ΡΟΥΣΣΟΣ	ΠΑΝΑΓΙΩΤΗΣ-ΑΛΕΞΑΝΔΡΟΣ	11784	Δ. ΛΟΥΚΑΣ	12/1/13	11/30/15		ΤΕΧΝΙΚΟΣ	ΑΝΑΘΕΣΗ ΕΡΓΟΥ
18	ΝΙΚΑΣ	ΔΗΜΗΤΡΙΟΣ	11784	Γ. ΦΑΝΟΥΡΑΚΗΣ	7/1/14	10/30/15	1/11 - 31/12/2015	PhD	ΑΝΑΘΕΣΗ ΕΡΓΟΥ
19	ΔΑΝΟΥΣΗΣ	ΣΠΥΡΙΔΩΝ	11784	Χ. ΜΑΡΚΟΥ	7/1/14	12/31/15	ΔΙΑΚΟΠΗ 19/10/2015	ΤΕΧΝΙΚΟΣ	ΑΝΑΘΕΣΗ ΕΡΓΟΥ
20	ΜΑΡΑΓΚΟΣ	ΝΙΚΟΛΑΟΣ	11784	ΣΤΑΥΡΟΠΟΥΛΟΣ	8/10/14	12/31/15		PhD	ΑΝΑΘΕΣΗ ΕΡΓΟΥ
21	ΔΡΑΓΓΙΩΤΗΣ	ΠΕΤΡΟΣ	11784	ΠΑΠΑΔΟΠΟΥΛΟΣ	11/1/14	7/31/15	20/10 - 31/12/2015	PhD	ΑΝΑΘΕΣΗ ΕΡΓΟΥ
22	ΜΠΑΓΑΤΕΛΑΣ	ΧΡΗΣΤΟΣ	11701	Χ. ΜΑΡΚΟΥ	2/1/14	9/30/15		Πτυχίο - Φυσικός	ΑΝΑΘΕΣΗ ΕΡΓΟΥ
			11795	ΧΑΡΙΣΟΠΟΥΛΟΣ	7/25/16	7/24/17			ΑΝΑΘΕΣΗ ΕΡΓΟΥ
			12147	ΜΑΡΚΟΥ	9/25/17	9/24/18			ΕΡΓΑΣΙΑΣ
			12147	ΜΑΡΚΟΥ	9/25/17	9/24/18			ΕΡΓΑΣΙΑΣ
23	ΠΙΚΟΥΝΗΣ	ΚΩΝ/ΝΟΣ	11701	Χ. ΜΑΡΚΟΥ	2/1/14	9/30/15		Μεταπτυχ/κός Φοιτητής	ΑΝΑΘΕΣΗ ΕΡΓΟΥ
			11795	ΧΑΡΙΣΟΠΟΥΛΟΣ	12/25/15	10/15/16	16/10/2016-15/4/2017		ΑΝΑΘΕΣΗ ΕΡΓΟΥ
			12147	ΜΑΡΚΟΥ	9/1/17	2/28/18			ΑΝΑΘΕΣΗ ΕΡΓΟΥ
24	ΛΕΝΗΣ	ΔΗΜΗΤΡΙΟΣ	11750	ΣΤΑΥΡΟΠΟΥΛΟΣ	3/1/14	6/30/15	5/9/2015-31/10/2015	PhD	ΑΝΑΘΕΣΗ ΕΡΓΟΥ
25	ΧΑΒΙΑΡΑ	ΑΡΤΕΜΗ	11775	Χ. ΜΑΡΚΟΥ	4/16/14	4/15/15			ΑΝΑΘΕΣΗ ΕΡΓΟΥ
26	ΔΑΜΙΑΝΟΣ	ΠΑΝΑΓΙΩΤΗΣ	11701	ΜΑΡΚΟΥ	7/4/14	9/30/15		PhD	ΑΝΑΘΕΣΗ ΕΡΓΟΥ
27	ΑΝΔΡΟΥΛΑΚΗΣ	ΓΕΩΡΓΙΟΣ	11701	ΜΑΡΚΟΥ	7/4/14	6/30/15	1/7-30/9/2015	Πτυχίο - Φυσικός	ΑΝΑΘΕΣΗ ΕΡΓΟΥ
			11795	ΧΑΡΙΣΟΠΟΥΛΟΣ	2/22/16	6/21/16	22/6/2016-21/6/2017		ΑΝΑΘΕΣΗ ΕΡΓΟΥ
			12147	ΜΑΡΚΟΥ	9/1/17	8/31/18			ΑΝΑΘΕΣΗ ΕΡΓΟΥ
28	TOMMASINI	DAMIANO	11756	ΠΑΠΑΔΟΠΟΥΛΟΣ	7/1/14	6/30/15		PhD	ΑΝΑΘΕΣΗ ΕΡΓΟΥ
29	WEVER	CHRISTOPHER	11756	ΠΑΠΑΔΟΠΟΥΛΟΣ	7/1/14	6/30/15		PhD	ΑΝΑΘΕΣΗ ΕΡΓΟΥ
30	FRELLESVIG	HJALTE	11829	ΠΑΠΑΔΟΠΟΥΛΟΣ	8/1/14	7/31/17		PhD	ΑΝΑΘΕΣΗ ΕΡΓΟΥ
31	ΜΙΧΟΣ	ΘΕΟΔΩΡΟΣ	11795	ΧΑΡΙΣΟΠΟΥΛΟΣ	10/1/14	6/30/16	31/3/2017	ΤΕΧΝΙΚΟΣ	ΑΝΑΘΕΣΗ ΕΡΓΟΥ
32	ΔΡΑΚΟΠΟΥΛΟΥ	ΕΥΑΓΓΕΛΙΑ	11701	ΜΑΡΚΟΥ	12/1/14	9/30/15		PhD	ΑΝΑΘΕΣΗ ΕΡΓΟΥ
33	ΚΟΥΤΣΟΥΚΟΣ	ΣΠΥΡΙΔΩΝ	11750	ΣΤΑΥΡΟΠΟΥΛΟΣ	2/1/13	1/31/14	1/8-31/10/2015	Πτυχίο - Φυσικός	ΑΝΑΘΕΣΗ ΕΡΓΟΥ
			12147	ΜΑΡΚΟΥ	4/2/18	9/30/18			ΕΡΓΑΣΙΑΣ
34	ΔΟΜΒΟΓΛΟΥ	ΘΕΟΔΩΡΟΣ	11750	ΣΤΑΥΡΟΠΟΥΛΟΣ	2/1/13	1/31/14	1/2/2014-30/6/2015	ΤΕΙ - Ηλεκτρονικός	ΑΝΑΘΕΣΗ ΕΡΓΟΥ
35	ΔΗΜΟΥ	ΣΩΤΗΡΙΑ	11750	ΣΤΑΥΡΟΠΟΥΛΟΣ	2/1/14	6/30/15	5/9 - 31/10/2015	Computer Engineer	ΑΝΑΘΕΣΗ ΕΡΓΟΥ
36	ΠΡΟΒΑΤΑΣ	ΓΕΩΡΓΙΟΣ	11775	Χ. ΜΑΡΚΟΥ	11/24/14	5/12/15		PhD	ΑΝΑΘΕΣΗ ΕΡΓΟΥ

			11928		4/18/16	8/31/16			ΑΝΑΘΕΣΗ ΕΡΓΟΥ	SIEMENS
37	ΨΑΛΙΔΑΣ	ΑΝΔΡΕΑΣ	11784	ΓΕΡΑΛΗΣ	1/26/15	12/31/15		PhD	ΑΝΑΘΕΣΗ ΕΡΓΟΥ	
38	KARDOS	ADAM	11756	ΠΑΠΑΔΟΠΟΥΛΟΣ	5/18/15	9/18/15		PhD	ΑΝΑΘΕΣΗ ΕΡΓΟΥ	
39	ΒΑΓΓΕΛΑΤΟΣ	ΕΥΘΥΜΙΟΣ	11724	ΧΑΡΙΣΟΠΟΥΛΟΣ	8/17/15	12/31/15		ΝΑΥΠΗΓΟΣ	ΑΝΑΘΕΣΗ ΕΡΓΟΥ	
40	ΓΕΩΡΓΑΝΤΑΣ	ΚΩΝ/ΝΟΣ	11724	ΧΑΡΙΣΟΠΟΥΛΟΣ	8/17/15	12/31/15		ΛΟΓΙΣΤΗΣ	ΑΝΑΘΕΣΗ ΕΡΓΟΥ	
41	ΨΑΛΛΙΔΑΣ	ΑΝΔΡΕΑΣ	11784	Γ. ΦΑΝΟΥΡΑΚΗΣ	1/26/15	12/31/15	ΔΙΑΚΟΠΗ 30/9/2015	PhD	ΑΝΑΘΕΣΗ ΕΡΓΟΥ	
42	ΜΠΑΛΑΣΗ	ΚΩΝΣΤΑΝΤΙΑ	1701	ΜΑΡΚΟΥ	3/1/13	2/28/14	1/3/2014-28/2/2015	PhD	ΑΝΑΘΕΣΗ ΕΡΓΟΥ	
			11784	ΣΤΑΥΡΟΠΟΥΛΟΣ	5/1/15	11/30/15		PhD	ΑΝΑΘΕΣΗ ΕΡΓΟΥ	
43	ΑΘΑΝΑΣΟΠΟΥΛΟΣ	ΘΕΟΔΩΡΟΣ	11750	ΣΤΑΥΡΟΠΟΥΛΟΣ	5/8/15	6/30/15	1/8/2015 - 7/9/2015	ΑΕΙ - Ηλεκτρονικός	ΑΝΑΘΕΣΗ ΕΡΓΟΥ	
44	ΟΙΚΟΝΟΜΟΥ	ΑΡΤΕΜΙΟΣ	1775	ΜΑΡΚΟΥ	3/20/14	11/19/14		PhD	ΑΝΑΘΕΣΗ ΕΡΓΟΥ	
45	ΜΑΝΙΑΤΗΣ	ΕΜΜΑΝΟΥΗΛ	11750	ΣΤΑΥΡΟΠΟΥΛΟΣ	12/1/13	11/30/14		Μεταπτυχιακό - Ηλεκτρονικός	ΑΝΑΘΕΣΗ ΕΡΓΟΥ	
46	ΣΜΥΡΗΣ	ΓΕΩΡΓΙΟΣ	11795	ΧΑΡΙΣΟΠΟΥΛΟΣ	4/1/16	12/31/16	1/2 - 30/4/4017	ΔΙΚΤΥΑΚΟΣ ΥΠΕΥΘΥΝΟΣ	ΑΝΑΘΕΣΗΣ ΕΡΓΟΥ	
			11730	ΠΡΟΕΔΡΟΣ	11/1/17	4/30/18			ΑΝΑΘΕΣΗΣ ΕΡΓΟΥ	
47	ΦΡΑΓΚΟΠΟΥΛΟΥ	ΜΑΡΙΑΝΘΗ	12149	ΠΡΟΕΔΡΟΣ	5/7/2018	3/7/2019		PhD	ΕΡΓΑΣΙΑΣ	ΙΔΡΥΜΑ ΣΤ.ΝΙΑΡΧ ΟΣ
48	ΠΑΣΠΑΛΑΚΗ	ΓΑΡΥΦΑΛΛΙΑ	12217	ΚΥΡΙΑΚΗΣ	1/11/2018	15/12/18	31/1/2019	Μεταπτυχ/κή Φοιτήτρια	ΕΡΓΑΣΙΑΣ	

Summary

I.N.P.P	2015	2016	2017
Personnel			
Scientific, Technical, Administrative, Postdoc, PhD Students, Associates	46	40	32
Financial Data (in euros €)			
Regular Public Funding	1.237.000	1.428.000	1.154.000
R&D projects, national and international	204.000	403.000	626.000
Services to third parties	9.000	18.000	0
Scientific Achievements			
Publications	87	82	81
Citations	>1200	>1200	>1200
PhD completed	3	1	2
Patents			

FUNDING ID

ΚΩΔΙΚΟΣ ΕΡΓΟΥ	ΤΙΤΛΟΣ	ΕΠΙΣΤΗΜΟΝΙΚΟΣ ΥΠΕΥΘΥΝΟΣ	ΕΝΑΡΞΗ	ΛΗΞΗ	ΠΡΟΫΠ/ΣΜΟΣ	ΦΟΡΕΑΣ ΧΡΗΜΑΤΟΔΟΤΗΣΗΣ
10200	Σύνδεση CERN με παραγωγικούς φορείς. Διάδοση προκηρύξεων CERN	ΔΙΕΥΘΥΝΤΗΣ ΙΠΣΦ	2/24/95	11/29/15	470,205.43 €	ΓΓΕΤ
10231	Μη καταστρεπτικές αναλύσεις με ακτίνες Χ	ΚΑΡΥΔΑΣ ΑΝΔΡΕΑΣ-ΓΕΡΜΑΝΟΣ	4/1/98	5/31/19	50,000.00 €	"Δ" (Εσωτερικό Έργο) - Δημόσιος και Ιδιωτικός Φορέας, Παροχή Εξειδικευμένων Ερευνητικών Υπηρεσιών
10461	Υποστήριξη Πυρηνικής και Σωματιδιακής Φυσικής	ΔΙΕΥΘΥΝΤΗΣ ΙΠΣΦ	7/28/98	1/27/19	1,161,076.00 €	"Δ" (Υποστήριξη Ερευν.Προγραμ.Ινστ.)
10881	Μικροσυστήματα ανιχνευτικών διατάξεων	ΛΟΥΚΑΣ ΔΗΜΗΤΡΙΟΣ	12/1/02	12/31/17	650,000.00 €	"Δ" (Εσωτερικό Έργο)
11041	ΑΤΕ2 (Ανάπτυξη Τεχνολογίας για Έρευνα και Εκπαίδευση)	ΦΑΝΟΥΡΑΚΗΣ ΓΕΩΡΓΙΟΣ	12/11/02	12/21/17	60,000.00 €	"Δ" (Εσωτερικό Έργο χρηματοδοτούμενο από εισπράξεις έμμεσων εξόδων)
11458	Φαινομενολογία Στοιχειωδών σωματιδίων	ΠΑΠΑΔΟΠΟΥΛΟΣ ΚΩΝ/ΝΟΣ	3/1/07	2/28/19	90,000.00 €	"Δ" (Εσωτερικό Έργο χρηματοδοτούμενο από εισπράξεις έμμεσων εξόδων)
11476	ESF Workshop on Stable Beams	ΧΑΡΙΣΟΠΟΥΛΟΣ ΣΩΤΗΡΙΟΣ	10/1/07	12/17/13	15,000.00 €	Δημόσιου & Ιδιωτικού Φορέα (Παροχής Υπηρεσιών
11545	LIBRA - Center of Excellence in Low-Energy Ion-Beam Research and Applications	ΧΑΡΙΣΟΠΟΥΛΟΣ ΣΩΤΗΡΙΟΣ	1/1/09	12/31/12	1,403,398.00 €	Ε.Ε. (7ο Πρόγραμμα Πλαίσιο, Capacities, REGPOT)
11551	ΣΥΝΤΗΞΗ - Ακτινοβολήσεις TANDEM	ΧΑΡΙΣΟΠΟΥΛΟΣ ΣΩΤΗΡΙΟΣ	12/1/08	12/31/18	50,000.00 €	"Δ", ΚΟΙΝΟΠΡΑΞΙΑ
11622	ENSAR- European Nuclear Science and Applications Research	ΧΑΡΙΣΟΠΟΥΛΟΣ ΣΩΤΗΡΙΟΣ	9/1/10	8/31/14	112,670.00 €	Ε.Ε. (7ο Πρόγραμμα Πλαίσιο, Capacities, Research infrastructures)
11701	GRBNeT - Μελέτη, σχεδιασμός, κατασκευή και πόντιση αυτόνομης γραμμικής συστοιχίας ανιχνευτών νετρίνο σε μεγάλο θαλάσσιο βάθος για τη διερεύνηση της φύσεως των Εκλάμψεων ακτίνων -γ	ΜΑΡΚΟΥ ΧΡΗΣΤΟΣ	3/1/12	12/14/15	540,000.00 €	ΕΣΠΑ, ΘΑΛΗΣ
11710	Αναζήτηση των ουδετέρων SM και MSSM μποζονίων Higgs στο κανάλι H/A/h tautau	ΔΑΣΚΑΛΑΚΗΣ ΓΕΩΡΓΙΟΣ	12/1/11	5/31/15	29,900.00 €	ΔΙΕΘΝΗ, Δέσμη Προγρ. 2003-2005, Δέσμη Προγρ. του ΙΠΕ

11724	ΔΕΛΤΑ-ΒΕΡΕΝΙΚΗ (KM3NeT) Υποστηρικτικές εργασίες στο πλαίσιο της διεκδίκησης φιλοξενίας/εγκατάστασης στην Ελλάδα της πανευρωπαϊκής ερευνητικής υποδομής μεγάλης κλίμακας KILOMETER CUBE NEUTRINO TELESCOPE	ΧΑΡΙΣΟΠΟΥΛΟΣ ΣΩΤΗΡΙΟΣ	3/8/10	12/31/15	1,200,000.00 €	ΕΣΠΑ, ΓΓΕΤ, ΥΠΟΔΟΜΗ Ε&Τα
11750	Συσκευές ελέγχου σε Πραγματικό Χρόνο της Ποιότητας και της Ασφάλειας του Ελαιολάδου και άλλων Βρώσιμων Ελαίων	ΣΤΑΥΡΟΠΟΥΛΟΣ ΓΕΩΡΓΙΟΣ	10/20/12	10/31/15	416,100.00 €	ΕΣΠΑ, ΓΓΕΤ, ΣΥΝΕΡΓΑΣΙΑ 2011
11756	HOCTools - Υπολογισμοί και αλγόριθμοι για διορθώσεις ανώτερης τάξης σε σκεδάσεις υψηλών ενεργειών	ΠΑΠΑΔΟΠΟΥΛΟΣ ΚΩΝ/ΝΟΣ	9/26/12	10/31/15	243,000.00 €	ΕΣΠΑ, ΓΓΕΤ, ΑΡΙΣΤΕΙΑ, ΑΡΙΣΤΕΙΑ I
11775	RE3CAP -Ανάλυση, Ανάκτηση, Αναβίωση της Κλασσικής Αττικής Κεραμικής	ΜΑΡΚΟΥ ΧΡΗΣΤΟΣ	1/14/13	5/13/15	120,000.00 €	ΕΣΠΑ, ΓΓΕΤ, ΣΥΝΕΡΓΑΣΙΑ 2011
11776	Υποστήριξη δραστηριοτήτων έργων Αστροσωματιδιακής Φυσικής	ΜΑΡΚΟΥ ΧΡΗΣΤΟΣ	1/1/13	12/31/18	59,000.00 €	"Δ" (Εσωτερικό Έργο)
11784	ΟΡΑΣΥ- Εξερευνώντας το Ορατό και το Αόρατο Σύμπαν με επιταχυντές και καινοτόμους ανιχνευτές	ΔΙΕΥΘΥΝΤΗΣ ΙΠΣΦ	9/1/12	12/31/15	1,400,000.00 €	ΕΣΠΑ, ΓΓΕΤ, ΚΡΗΠΙΣ
11795	KM3NeT Studies (Deep Sea Facility in the Mediterranean for Neutrino Astronomy and Associated Sciences)	ΧΑΡΙΣΟΠΟΥΛΟΣ ΣΩΤΗΡΙΟΣ	4/1/13	9/25/17	327,064.50 €	"Δ" (Εσωτερικό Έργο)
11821	Ακτινοβολήσεις Υλικών	ΛΑΓΟΓΙΑΝΝΗΣ ΑΝΑΣΤΑΣΙΟΣ	7/1/13	6/30/17	6,000.00 €	"Δ" (Εσωτερικό Έργο)
11829	HiggsTools- The Higgs quest-exploring electroweak symmetry breaking at the LHC	ΠΑΠΑΔΟΠΟΥΛΟΣ ΚΩΝ/ΝΟΣ	1/1/14	12/31/17	249,514.32 €	Ε.Ε. (7ο Πρόγραμμα Πλαίσιο, People,Initial training of researchers)
11840	DEEP-CO-HOUS- Σχεδιασμός, Κατασκευή και Πειραματική Δοκιμή Δοχείων Πίεσης από Σύνθετα Υλικά για Μεγάλα Θαλάσσια Βάθη	ΡΑΠΙΔΗΣ ΠΕΤΡΟΣ	3/1/13	10/31/15	74,000.00 €	ΕΣΠΑ, ΓΓΕΤ, ΣΥΝΕΡΓΑΣΙΑ 2011
11893	Laboratory for Ion-Beam Research and Applications - LIBRA	ΧΑΡΙΣΟΠΟΥΛΟΣ ΣΩΤΗΡΙΟΣ	9/1/14	8/31/17	200,000.00 €	"Δ" (Εσωτερικό Έργο)
11900	MIXMAX-Development and Implementation of new generation of Pseudo Random Number Generators (PRNG) based on Kolmogorov-Anosov K-systems	ΣΑΒΒΙΔΗΣ ΓΕΩΡΓΙΟΣ	1/1/15	12/31/18	216,000.00 €	Ε.Ε.

11984	(Υποστήριξη Βραδιάς Ερευνητή)	ΦΑΝΟΥΡΑΚΗΣ ΓΕΩΡΓΙΟΣ	5/1/16	11/30/17		HORIZON 2020, Coordination & Support Action, European Researchers Night (NIGHT)
11985	ENSAR 2 — H2020	ΧΑΡΙΣΟΠΟΥΛΟΣ ΣΩΤΗΡΙΟΣ	1/3/2016	2/29/20	60,000.00 €	Ε.Ε - HORIZON 2020, Research & Development, Research & Innovation action
12147	KM3NET 2.0	ΜΑΡΚΟΥ ΧΡΗΣΤΟΣ	1/1/17	12/31/19	487,500.00 €	Ε.Ε. - HORIZON 2020
12149						ΙΔΡΥΜΑ ΣΤΑΥΡΟΣ ΝΙΑΡΧΟΣ
12157	Διεπιστημονικές αναλυτικές εφαρμογές με χρήση τεχνικών συγχροτρονίου και πειραματική μελέτη δευτέρας τάξεως μηχανισμών στην αλληλεπίδραση ακτίνων Χ με την ύλη	ΚΑΡΥΔΑΣ ΑΝΔΡΕΑΣ-ΓΕΡΜΑΝΟΣ	3/10/17	3/9/20	15,000.00 €	"Δ" (Εσωτερικό Έργο)
12164	Highly Miniaturized ASIC Radiation Detector	ΛΟΥΚΑΣ ΔΗΜΗΤΡΙΟΣ	3/7/17	10/6/18	40,987.00 €	European Space Agency
12209	ESSnuSB (Horizon 2020)	ΦΑΝΟΥΡΑΚΗΣ ΓΕΩΡΓΙΟΣ	1/1/18	12/31/21	64,953.00 €	Ε.Ε. - HORIZON 2020
12217	ΟΡΑΣΥ- Εξερευνώντας το Ορατό και το Αόρατο Σύμπαν : Τεχνολογία - Εξειδίκευση - Καινοτομία	ΔΙΕΥΘΥΝΤΗΣ ΙΠΣΦ	4/1/18	3/31/20	200,000.00 €	"Δ" (Εσωτερικό Έργο)

High Energy Experimental Physics

CMS group Activities Report 2015-2017
Institute of Nuclear and Particle Physics
NCSR Demokritos

A) The INPP_CMS group (as of June 1st, 2018)

The INPP CMS group has the following members assigned 100% to the CMS/Tracker project:

Researchers: G. Anagnostou, G. Daskalakis, A. Kyriakis, D. Loukas*
Doctoral students: P. Asenov, P. Assiouras, G. Paspalaki, I. Topsis-Giotis
Non-Doctoral students: G. Billis, A. Papadopoulos
Electronics Engineer: I. Kazas
Administration: M. Barone

* D. Loukas is the group representative

B) The INPP_CMS activities during 2015 - 2017

During the period 2015 – 2017 the INPP_CMS group was active in two different directions:

1) Physics analysis using the pp collision data at 8 TeV (2012) and 13 TeV (2015-2016-2017)
2) The CMS Upgrade effort devoted to the physics potential and the required sub-detectors CMS upgrades.

Since 2016 the members of the group that were working for the CMS ECAL moved to the activities of the CMS Tracker and the associated R&D work for the Phase II upgrade of the CMS experiment.

Service work

The INPP_CMS members contributed to running the experiment with shifts (Shift leader, Central DAQ, Trigger, ECAL and Online Monitor). They have also undertaken Service work within ECAL, TriDas, Tracker, DQM, Upgrade physics studies, etc. The INPP_CMS group contribution, in shifts and service work, corresponds to: 1) 2015: 20 months worked/37.25 required, i.e. 54% of the required quota, 2) 2016: 8.5 months worked/21.05 required, i.e. 40% of the required quota, 3) 2017: 11 months worked/21.63 required, i.e. 51% of the required quota. On average INPP_CMS has covered its obligation up to 48% of the required quota.

Physics Analyses

During 2015 – 2017 INPP_CMS invested primarily on the physics measurements using data of pp collisions at 8 TeV and 13 TeV. Members of the group played leading role in important analyses within CMS and were Analysis Review Committee (ARC) members. The physics studies focused on Standard Model, Supersymmetry, Higgs, Exotic Physics and are listed below:

1- Search for Exotic Particles, G. Daskalakis, V. Giakoumopoulou

Publication: CMS Collaboration **Phys. Lett. B768 (2017) 57-80, PAS-EXO-16-031, JHEP04 (2015) 025**

CMS Analysis Notes: **AN-2016/138, AN-2016/190, AN-2016/404, AN-2016-053, AN-2015/223, AN-2015/222, AN-2015/058**

Short description: A search for narrow resonances in dielectron and dimuon invariant mass spectra has been performed using data obtained from proton–proton collisions at sqrt(s) = 13 TeV collected with the CMS detector. The integrated luminosity for the dielectron sample is 2.7 fb^{-1} and for the dimuon sample 2.9 fb^{-1}. The sensitivity of the search is increased by combining these data with a previously analyzed set of data obtained at sqrt(s) = 8 TeV and corresponding to a luminosity of 20 fb^{-1}. No evidence for non-standard-model physics is found, either in the 13 TeV data set alone, or in the combined data set. Upper limits on the product of production cross section and branching fraction have also been calculated in a model-independent manner to enable interpretation in models predicting a narrow dielectron or dimuon resonance structure. Limits are set on the masses of hypothetical particles that could appear in new-physics scenarios. For the Z'_{SSM} particle, which arises in the sequential standard model, and for the superstring inspired Z'_{Ψ} particle, 95% confidence level lower mass limits for the combined data sets and combined channels are found to be 3.37 and 2.82 TeV, respectively. The corresponding limits for the lightest Kaluza–Klein graviton arising in the Randall–Sundrum model of extra dimensions with coupling parameters 0.01 and 0.10 are 1.46 and 3.11 TeV, respectively. These results significantly exceed the limits based on the 8 TeV LHC data.

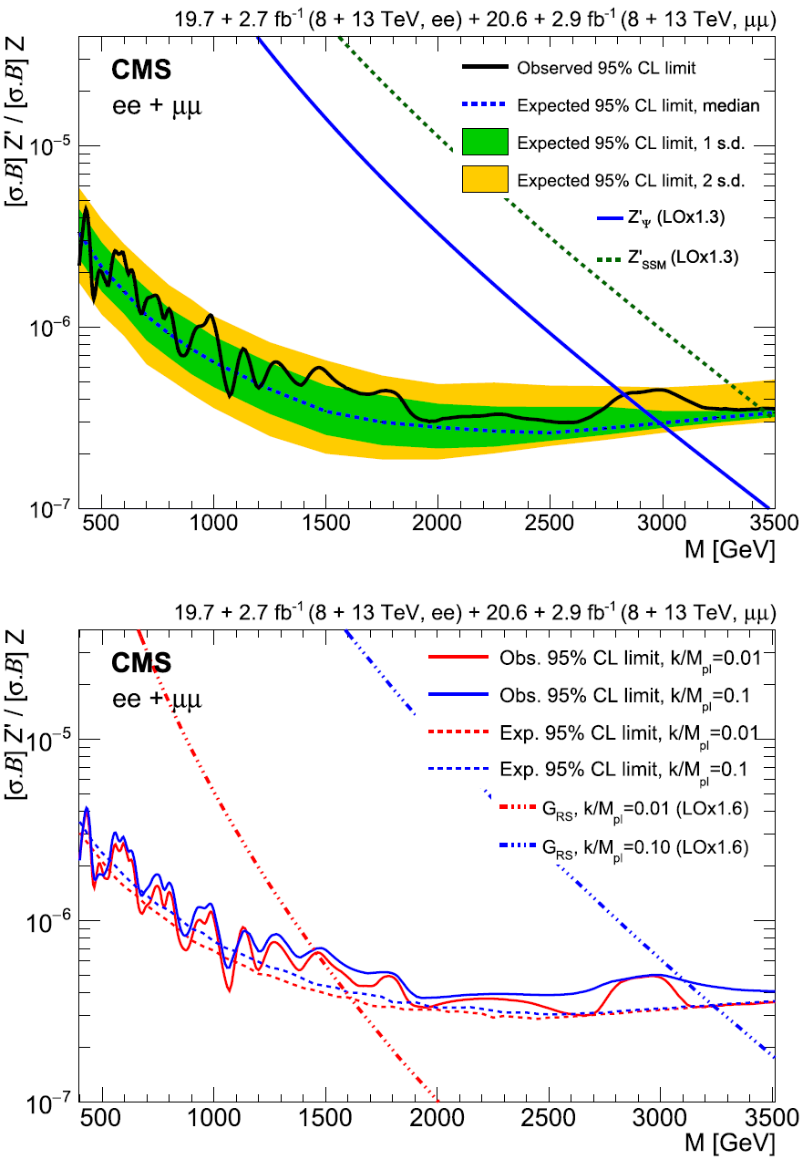


Fig. 6. The 95% CL upper limits on the product of production cross section and branching fraction for (top) a spin-1 resonance with a width equal to 0.6% of the resonance mass and (bottom) for a spin-2 RS graviton, both relative to the product of production cross section and branching fraction for a Z boson, for the combined dielectron and dimuon channels and combined 8 and 13 TeV data. For the spin-1 results (top plot), the shaded bands correspond to the 68 and 95% quantiles for the expected limits, and theoretical predictions are shown for the spin-1 Z'_{SSM} and Z'_{ψ} resonances. For the spin-2 results (bottom plot), observed limits, expected limits, and theoretical predictions are shown for values of the coupling parameter $k/\overline{M}_{Pl} =$ 0.01 and 0.10.

2- Search for final states with 2 invisible particles in the 2-Dimensional mass space

G. Anagnostou , A.Psallidas, S. Beranek , G. Daskalakis

CMS PAS:	**PAS-B2G-12-025**
Thesis:	**CERN-THESIS-2017-115**
CMS Analysis Notes:	**AN-2017/343**
CMS Conference Report:	**CR-2015/293**

Short description:

A simultaneous search for both a new heavy top partner and a new heavy charged gauge boson is performed using collision data recorded by the CMS detector corresponding to 19.7 fb^{-1} of integrated luminosity at 8 TeV. The final state has two charged leptons, two jets and missing transverse energy due to the invisible neutrinos. The analysis is based on a two-dimensional mass reconstruction of the TT' system. The analytic solutions together with constraints from the parton distribution functions (PDFs) are used to reconstruct the masses of two unknown particles simultaneously. The only assumption used in the mass reconstruction is that each T' decays to a W' and a b quark, with the heavy W' subsequently decaying into an electron or a muon, and a massless particle. Thus, the analysis is performed in a model independent way to target possible signals that may have not been predicted yet. A hypothetical signal, based on the littlest Higgs model is used to set 95% CL upper limits on the production cross section times branching ratio as a function of the T' and the W' mass. The analysis for Run1 was performed as a collaboration between Demokritos (G.Anagnostou, A.Psallidas) and Aachen University (PhD thesis of Mrs Sarah Beranek). The effort in Run2 is focused on analyzing the larger dataset available as well as to extend the topologies to those concerning dark matter searches.

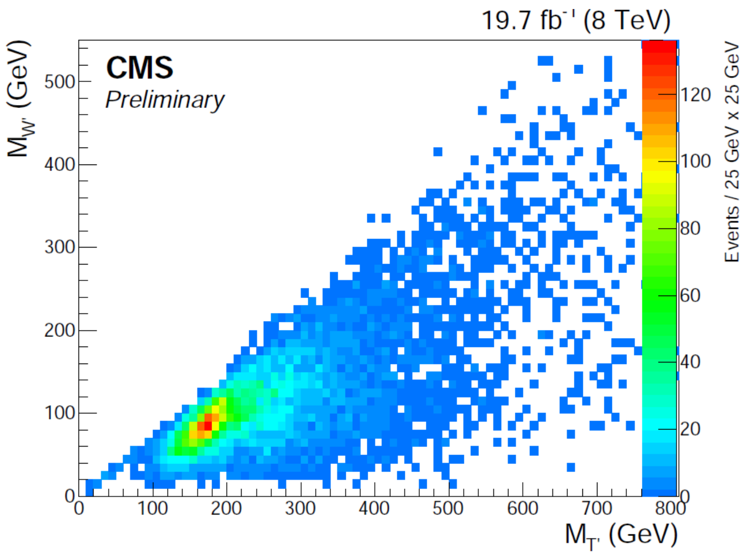


Figure 1: Mass reconstruction in two-dimensional mass space using 19.7 fb^{-1} at 8 TeV.

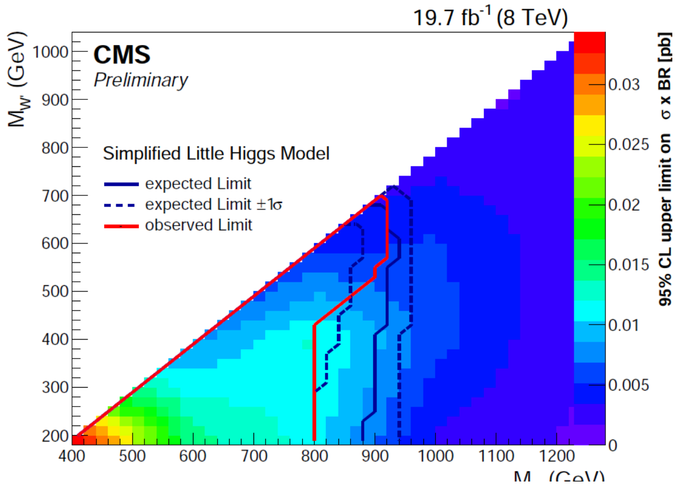


Figure 2: The expected and observed 95% CL upper limits on the cross-section x BR for the Little Higgs Model.

3- SUSY searches A. Kyriakis, I. Topsis-Giotis, G. Paspalaki

Publication: CMS Collaboration **Phys. Lett. B769 (2017) 391**

CMS Analysis Notes: **AN-2017/131, AN-2015/251**

Short description: The results of a search for new physics in final states with photons and missing transverse energy are reported. The study is based on a sample of proton–proton collisions collected at a center-of-mass energy of 13 TeV with the CMS detector in 2015, corresponding to an integrated luminosity of 2.3 fb^{-1}. Final states with two photons and significant missing transverse energy are used to search for supersymmetric particles in models of supersymmetry (SUSY) with general gauge-mediated (GGM) supersymmetry breaking. No excess is observed with respect to the standard model expectation, and the results are used to set limits on gluino pair production and squark pair production in the GGM SUSY framework. Gluino masses below 1.65 TeV and squark masses below 1.37 TeV are excluded at a 95% confidence level.

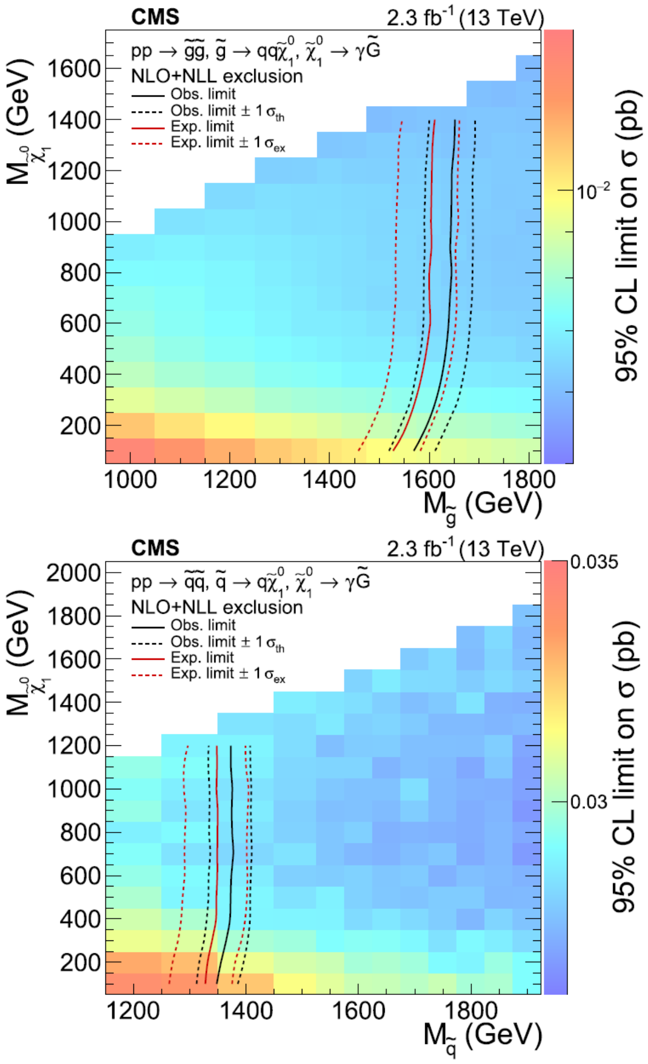


Fig. 4. The 95% CL upper limits on the gluino (top) and squark (bottom) pair production cross sections as a function of neutralino versus gluino (squark) mass. The contours show the observed and median expected exclusions assuming the NLO+NLL cross sections, with their one standard deviation uncertainties. The limit curves terminate at the centers of the bins used to sample the cross section.

4- HIGGS searches I.Topsis-Giotis

Publication: CMS Collaboration **Phys. Lett. B753 (2016) 363**

Short description: A search is presented for exotic decays of a Higgs boson into undetectable particles and one or two isolated photons in pp collisions at a center-of-mass energy of 8 TeV. The data correspond to an integrated luminosity of up to 19.4 fb^{-1} collected with the CMS detector at the LHC. Higgs bosons produced in gluon–gluon fusion and in association with a Z boson are investigated, using models in which the Higgs boson decays into a gravitino and a neutralino or a pair of neutralinos, followed by the decay of the neutralino to a gravitino and a photon. The selected events are consistent with the background-only hypothesis, and limits are placed on the product of cross sections and branching fractions. Assuming a standard model Higgs boson production cross section, a 95% confidence level upper limit is set on the branching fraction of a 125 GeV Higgs boson decaying into undetectable particles and one or two isolated photons as a function of the neutralino mass. For this class of models and neutralino masses from 1 to 120 GeV an upper limit in the range of 7 to 13% is obtained. Further results are given as a function of the neutralino lifetime, and also for a range of Higgs boson masses.

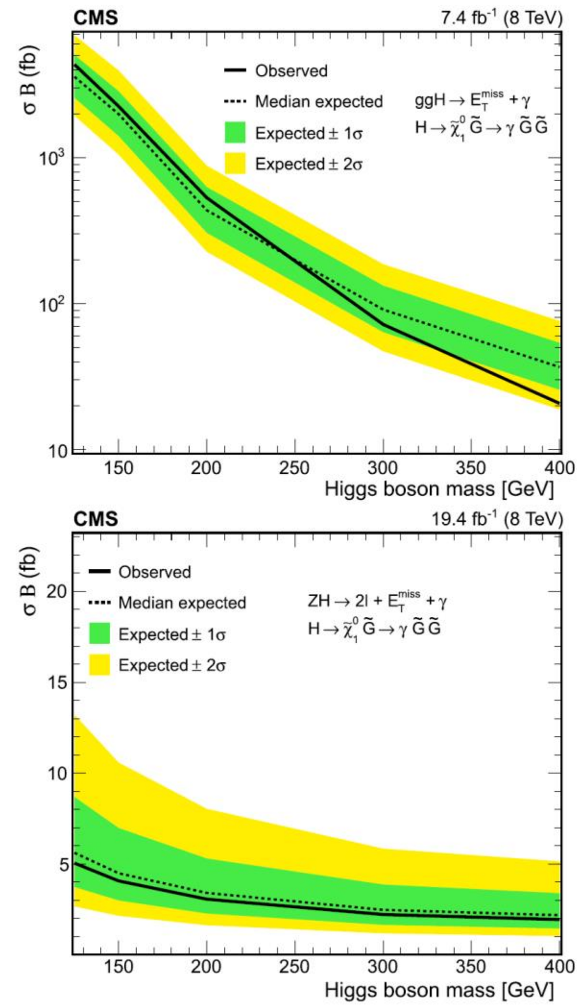


Fig. 7. Expected and observed 95% CL upper limits on $\sigma_{gg\to H}\mathcal{B}$ as a function of the Higgs boson mass with $m_{\tilde{\chi}_1^0} = m_H - 30$ GeV in ggH channel (top) and in the ZH channel (bottom).

5- Top Cross sections G. Daskalakis, G.Anagnostou, E.Elmalis, T. Diakonidis

Publication: CMS Collaboration, **PAS-TOP-15-006**

CMS Conference Report: **CR-2016/235**

Short description: The top-quark pair differential production cross section in pp collisions at sqrt(s) = 8 TeV as a function of the number of jets is measured in the lepton+jets (*e*/μ+jets) final state for an integrated luminosity of 19.7 fb^{-1}. The cross section is presented in the visible phase space of the measurement as well as extrapolated to the full phase space. The results are compared with theoretical predictions at next-to-leading order. The comparisons show good agreement between the data and the predictions within the experimental and theoretical uncertainties.

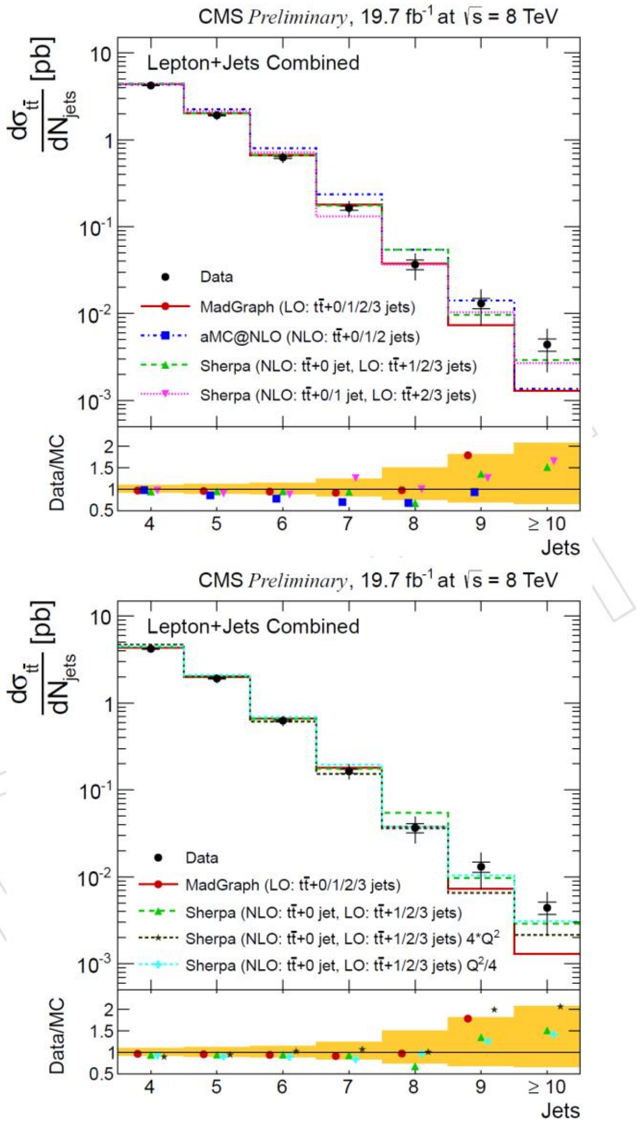


Figure 3: Combined differential visible $t\bar{t}$ cross section as a function of the number of particle-level jets in the ℓ+jets channel. The results are compared to predictions from various MC generators (top) and SHERPA Q^2 (bottom). The vertical bars represent the total uncertainties and the intersecting vertical bars represent the statistical uncertainties alone. In the ratio plot, the band represents the uncertainty of the measurement.

6- Flavor tagging performance G. Paspalaki

CMS Analysis Notes: **AN-2017/346**

Short description: This note describes the results on performance of b and c quark tagging algorithms with 42 fb^{-1} of data collected in 2017 at 13 TeV. Results encompass flavour tagging efficiency scale factor measurements using QCD muon-enriched multijet and top quark pair events. Mistag efficiency scale factors are measured in inclusive QCD multijet and Drell-Yan events. Comparisons between data and MC for various flavour tagging variables for standard AK4 jets and subjets in AK8 jets are presented.

7- R&D Phase II Upgrade of the end cap calorimeter T.Geralis, A. Psallidas, A. Kalamaris

Publications: **NIM A824(2016) 510511.**

Short description: Micromegas, as a proportional and compact gaseous detector, is well suited for sampling calorimetry. The limitation of occasional sparking has now been lifted by means of resistive electrodes but at the cost of current-dependent charge-up effects. These effects are studied in this contribution, with an emphasis on gain variations during operation at high particle rate and under heavy ionisation. Results are reproduced by a simple model of charging-up which will be used for detector design optimisation in the future.

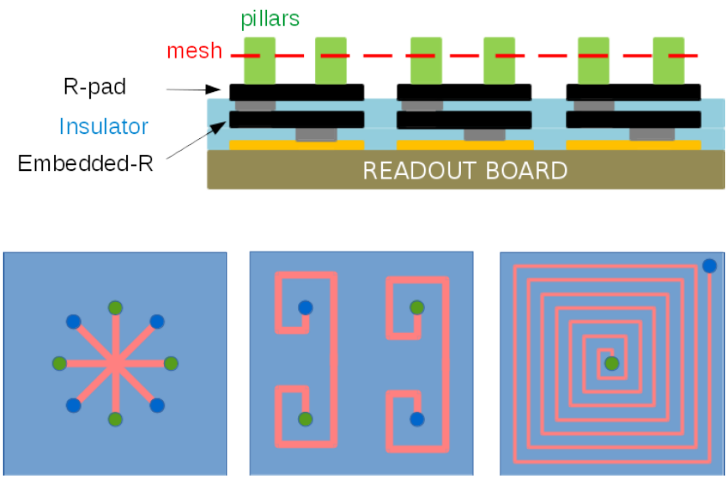


Figure 1: Not-to-scale drawing of a Micromegas with embedded resistor (top). Resistor patterns (bottom): blue and green dots are electrical connections of the embedded resistor to resistive and metalic pads respectively.

Institutional Reviews:

SMP-17-012, EXO-17-028, B2G-17-001, EXO-16-056, TOP-16-016, TOP-16-007, BPH-15-002 Most of the group members participated in Institutional Reviews for the approval of the CMS publications.

Analysis Review Committees:

- Georgios Anagnostou participated as ARC chair or member in the following publications: B2G-16-016, B2G-17-010, PAS-B2G-16-017, B2G-15-004, B2G-16-009
- Georgios Daskalakis participated as ARC chair or member in the following publications: EXO-16-050, EXO-16-010, EXO-16-038, HIN-16-014, HIN-15-002, SMP-15-004

CMS Upgrade activities during 2015 - 2017

In preparation for the CMS upgrade our group participated in two R&Ds for developing Si and Micromegas detector prototypes appropriate for the HL-LHC and the Phase II CMS Upgrade. We have also participated in Physics studies for detector optimization and best physics output. In more details we have performed:

Physics studies and reconstruction software development.

1) Optimization of the pseudorapidity coverage to higher values in CMS for studying Vector Boson scattering at HL-LHC. G. Anagnostou and T. Geralis (6 group presentations in CMS).
2) Study of Particle Flow (PandoraPFA) algorithms for the High Granularity Calorimeter (HGCAL) for the HL-LHC at high pile-up (140). T. Geralis and A. Psallidas (more than 20 presentations at CMS).

Detector development for the HL-LHC

During this period the group has initiated two R&Ds on detector instrumentation that reflect the relevant activities within the INPP.

- One is referred to the development of Si sensors for the Central Tracker Pixel detector and the second
- on the development of Micromegas, micro pattern gaseous detectors, for hadron calorimetry at high rates and high luminosity.

The CMS experiment has not adopted the Micromegas option and the associated activity in INPP has been moved to ATLAS experiment forming a new group.
Since 2015 the CMS INPP group moved from ECAL to the Tracker group.

Contribution of INPP to the CMS Tracker Project (2015-2017)

The activities of the INPP CMS Tracker group are deployed across the fronts of maintenance and operation of the current tracker detector and the developmental work for the phase II upgrade of the CMS Tracker.

Operation of the Current Tracker Detector:

The group assumes the main responsibility for the development and maintenance of the web interface of the ***Historic Data Quality Manager*** (***HDQM***[1]) of the CMS Tracker Detector. The main responsibility for the everyday monitoring, and action taking, is taken on by Dr. Aris Kyriakis while our computer engineer student Alkis Papadopoulos is developing the front-end web application. "Hdqm" plots in a dynamic and interactive way observables (mean values, occupancies cluster sizes etc), of the tracker modules, extracted from the on-line dqm data base. It traces the evolution in time of the observables and provides a quick look to the physicists for the quality of the runs. The Tracker Hdqm has been evaluated as a useful tool by the CMS collaboration and a working group is formed in order to extent its applicability as a global CMS tool.

[1] Web page: https://twiki.cern.ch/twiki/bin/viewauth/CMS/TrackerHDQM

The CMS Phase-2 Upgrade and the Contribution of INPP to the CMS Tracker Upgrade

The CMS detector needs to be substantially upgraded during LS3 in order to exploit the
ncrease in luminosity provided by the HL-LHC . This upgrade is referred to as the CMS Phase-2 Upgrade. The increase in radiation levels requires improved radiation hardness, while the larger pileup and associated increase in particle density requires higher detector granularity to reduce occupancy, increased bandwidth to accommodate higher data rates, and improved rigger capability to keep the trigger rate at an acceptable level while not compromising physics potential.

The entire silicon tracking system, presently consisting of pixel and strip detectors, will be replaced. The new tracker will feature increased forward acceptance, increased radiation hardness, higher granularity, and compatibility with higher data rates and a longer trigger latency. In addition, the tracker will provide tracking information (on tracks above a configurable transverse momentum threshold) to the L1 trigger, information presently only available at the HLT. This will allow the trigger rates to be kept at a sustainable level without sacrificing physics potential.

The new modules are composed of two single-sided closely-spaced sensors read out by a common set off ront-end ASICs that correlate the signals in the two sensors and select the hit pairs (referred to as "stubs") compatible with particles above the chosen p_T threshold. Modules composed of two microstrip sensors are named as 2S while modules composed of one microstrip sensor and one micropixel are named as PS.

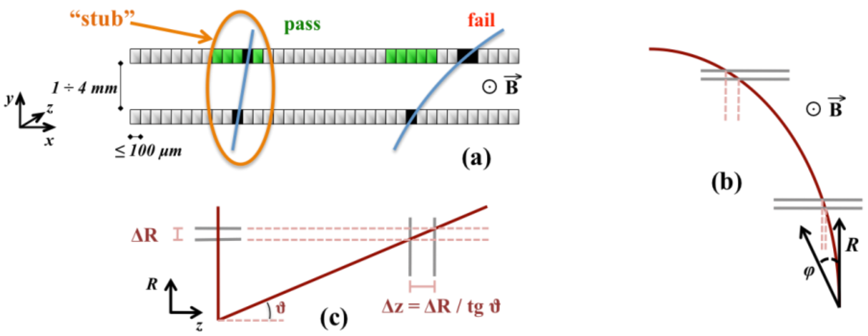


Figure : Illustration of the pT module concept. (a) Correlation of signals in closely-spaced sensors enables rejection of low-pT particles; the channels shown in green represent the selection window to define an accepted stub. (b) The same transverse momentum corresponds to a larger distance between the two signals at large radii for a given sensor spacing. (c) For the endcap discs, a larger spacing between the sensors is needed to achieve the same discriminating power as in the barrel at the same radius.

The INPP CMS Tracker group is contributing to the Sensor Quality Control (SQC) and to the Process Quality Control (PQC). A substantial work goes to the development of a test bench locally in the INPP that will permit the familiarity, and the development of expertise, with the full chain of data acquisition and effective participation of the members of our group to test beams at CERN and the commissioning of the detector later on.

Two new PhD students joined our group in 2016. Panagiotis Assiouras is currently working of the simulation of silicon sensor capacitances. Patrick Asenov is working with Geant4 on the simulation of the response of the Outer Tracker Modules to various particles.

Figure 1 shows the automated system for measurements of the phase II tracker sensors that we set up in our laboratory. It consists of a probe station and electrical characterization equipment controlled by a LabView program.

Participation to Beam Tests at CERN

During November 2015, our group participated to Beam Test (BT) of two 2S modules using π^+ beam at 120 GeV. A particle telescope developed by the collaboration AIDA (http://aida2020.web.cern.ch/) has been used for tracks reconstruction. The 2S module has been tested for various variable scans, in particular a threshold scan of the so called CBC2 readout chip, an angular scan to simulate the effect of the magnetic field and a X-Y position scan. This work is included in the PhD thesis of Iassonas Topsis-Giotis.

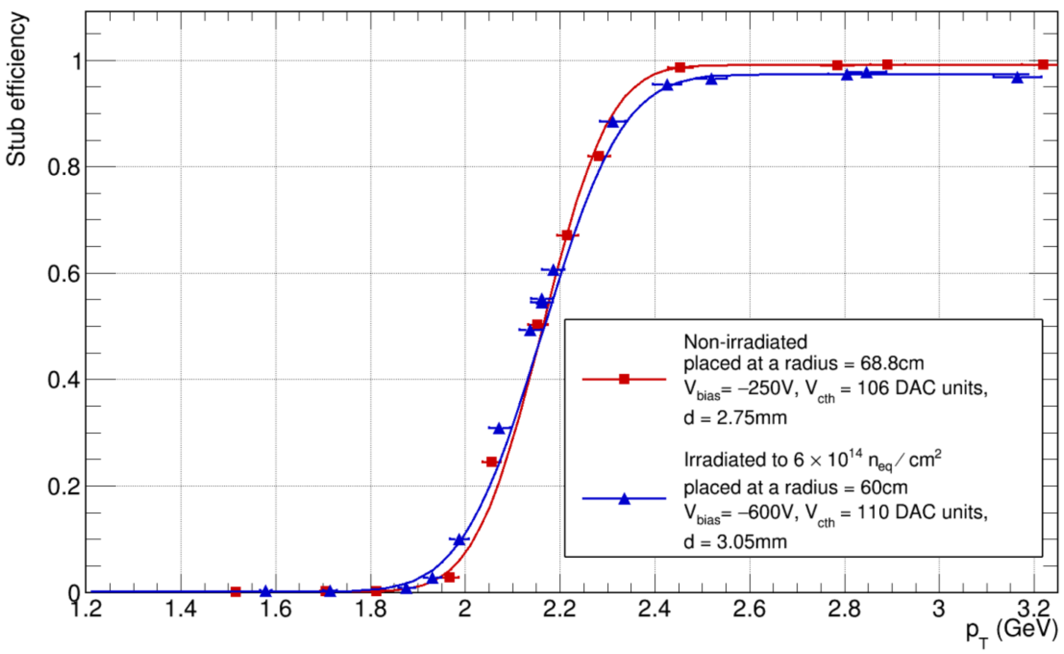


Figure : Stub reconstruction efficiency for a non-irradiated (red) and an irradiated (blue) 2S mini-module. The mini-module was irradiated to a fluence of 6 _ 1014 neq/cm2. The variable Vcth refers to the threshold setting, while d is the sensor spacing. The thresholds used correspond to about 4900 and 3500 electrons for the unirradiated and irradiated module, respectively. Radii of 69 cm and 60 cm were used for the calculation of the pT from the tilt angle of the non-irradiated and irradiated module, respectively The different radii compensate for the fact that the modules had different sensor spacing but were operated with the same stub acceptance window. The measurement was carried out at the CERN H6B beam line using 120 GeV pions.

Figure 1: The fully automated system of the INPP for the SQC and PQC of the phase II CMS tracker

C) INPP_CMS planning for 2018 and beyond

The LHC will be delivering pp collisions at 13 TeV at 2018 and our group will continue with extended effort on running the experiment and performing analyses at this new uncharted physics domain. Our group plans to cover the required 4 months of service work/year/author. The analysis work will continue in the same physics directions in order to extend their potential to this new high energy physics front. New analysis will be included in our research program according to the potential that will emerge during the 13 TeV data taking. One major concern is the termination of all the projects (THALIS-DIBOSON, THALIS-GENESIS and KRIPIS) that funded our activities by the end of 2015. A list of all the on-going analyses is given below:

1) Search for exotic particles
2) Model independent search in 2-Dimentional mass space
3) Higgs Physics
4) Top Physics

In parallel, the activity on the instrumentation will continue as it is described in the upgrades plans. With the commissioning of the Phase I detectors the CMS experiment is focusing his activities on the maintenance and operation of the current experimental setup and the developmental work for the Phase II upgrade. The first CMS Technical Design Report (TDR) for the Phase II upgrade is the Tracker one and it is now published. Our group contributes with participation to beam tests and electrical measurements of silicon detector prototypes and our silicon lab is one of the four sensor Process Quality Centers (PQC) for the CMS Phase II Tracker.

Details on physics measurements

1. Measurement of the W boson helicity fractions in $t\bar{t}$ events

The main goal of this part of the proposal is the deeper understanding of processes and mechanisms described by the Standard Model (SM) of particle physics and the investigation for possible discrepancies from the current predictions of the SM. Our objective is to enhance the experience gained over the past few years, based on electroweak measurements, by investing in studies in the field of top-quarks physics. Specifically, we would like to perform a measurement of the W boson helicity fractions in $t\bar{t}$ events using data from pp collisions at a centre-of-mass energy of 13 TeV. The comparison of the measured W helicity fractions with those estimated from the theory might reveal possible discrepancies from the SM predictions and contribute to a deeper understanding of the underlying physics processes.

2. Search for general gauge mediated supersymmetry in events with photons, jets, and missing transverse momentum

The main goal of this part of the proposal is to investigate the existence of supersymmetry by testing the Models with general gauge mediation (GGM) that can have a wide range of features, but typically entail a gravitino LSP and a next-to-lightest supersymmetric particle (NLSP) commonly taken to be a neutralino or a stau. Supersymmetry is one of the most promising theories beyond Standard Model to solve among others the hierarchy problem. The search will be done using data already collected or expected to be collected by the CMS/LHC experiment at 13 TeV center of mass energy during 2017 and 2018.

3. New model independent methods to search for particles of unknown masses in events with missing energy.

The method was motivated/inspired as a new/different way to search for final states with two invisible particles, a typical signature for dark matter particles at the LHC. A typical supersymmetric cascade has a topology which is similar to the dilepton top pairs, with two invisible particles in the end of the cascade. In Run1, a search for heavy top partners was performed as a proof of principle. But it is now time to apply the method for the initial goal for which it was designed: the hunt for invisible particles at the LHC. It is quite generic and can be applied to many topologies concerning dark matter searches with leptons, jets and missing energy.

The CMS Tracker Upgrade

During shutdown foreseen for the period 2024-2026 (Long Shutdown 3, LS3) the LHC accelerator will be upgraded to Higher Luminosity (HL-LHC) enable instantaneous peak luminosities of 5×10^{34} cm^{-2} s^{-1}, or even 7.5×10^{34} cm^{-2} s^{-1} in the ultimate performance scenario. This will allow CMS to collect integrated luminosity of the order of 300 fb^{-1} per year and up to 3000 fb^{-1} during the HL-LHC projected lifetime of ten years (up to 4000 fb^{-1} if the ultimate instantaneous luminosity is achieved). The HL-LHC is expected to run at a centre-of-mass energy of 14 TeV and with a bunch spacing of 25 ns. The HL-LHC project was formally approved by CERN Council in June 2016. The HL-LHC upgrade and its full exploitation is considered a top priority effort by the European Strategy for Particle Physics (ESPP) and the US Particle Physics Project Prioritization Panel (P5), and is in the landmark list of the European Strategy Forum on Research Infrastructures (ESFRI) "Roadmap 2016" strategy report on large research infrastructures.

The entire CMS silicon tracking system, presently consisting of pixel and strip detectors, will be replaced after ~300 fb^{-1}. The new tracker will feature increased forward acceptance, increased radiation hardness, higher granularity, compatibility with higher data rates and a longer trigger latency. In addition, the tracker will provide tracking information (on tracks above a configurable transverse momentum threshold) to the L1 trigger, information presently only available at the HLT. This will allow the trigger rates to be kept at a sustainable level without sacrificing physics potential.

The Phase II CMS Tracker is a single system in its operation that includes an *Inner* part made of pixel modules and an *Outer* part made of microstrip and macro-pixel modules. The inner detector has a total of 1.947.000.000 individual channels while the Outer detector incorporates a total of 193.520.640 channels that must be tested and characterized one by one. Each individual channel includes a silicon diode and the VLSI mixed analogue-digital electronics for processing of the analogue information provided by the incoming charged particles.

The CMS group of the Institute of Nuclear and Particle Physics (INPP) operating within the National Center for Scientific Research DEMOKRITOS (NCSR "D") has expressed interest to specific construction responsibilities. These responsibilities include Sensor Quality Control, Process Quality Control, development of electronics for the front-end Application Specific Integrated Circuits (ASICs) and Hybrids as well as the integration of subsystems towards the commissioning and installation of the detector.

A strategic research policy decision was taken in the early nineties regarding the development of a local silicon instrumentation laboratory in NCSR "D", aiming to assist the R&D program of the High Energy community with construction activities at National level and promote collaboration with industry. The so-called Detector Instrumentation Laboratory (DIL) was created. In the Phase-I of the CMS experiment our group embarked into the development of the Si sensors for the Preshower sub-detector and the construction of one thousand modules (one quarter of their total number) that were installed in the CMS experiment and are currently taking data.

Publications associated with Sensors & VLSI electronics

[1] D. Chatzistratis, G. Theodoratos, I. Kazas, E. Zervakis , D. Loukas and C. P. Lambropouolos, "Architecture and characterization of the P4DI CMOS hybrid pixel sensor," *Journal of Instrumentation,* vol. 12, 26 September 2017.

[3] W. Adam and et al., "Characterisation of irradiated thin silicon sensors for the CMS phase II pixel upgrade,"*The European Physical Journal C,* p. 567, 1 August 2017.

[4] W. Adam and et al., "P-Type Silicon Strip Sensors for the new CMS Tracker at HL-LHC," *Journal of Instrumentation,* vol. 12, no. 06, p. P06018, 27 June 2017.

[5] Y. Skovpen and et al., "Mechanical stability of the CMS strip tracker measured with a laser alignment system," *Journal of Instrumentation,* vol. 12, no. 4, 21 April 2017.

[6] D. Hatzistratis, G. Theodoratos, E. Zervakis, D. Loukas and C. P. Lambropouos, "CMOS Pixel Spectroscopic Circuits for Cd (Zn) Te Gamma Ray Imagers," in *MATEC Web of Conferences, DOI: 10.105/matecconf/20164103002,* 2016.

[7] C. Papadimitropoulos, I. Kaissas, C. Potiriadis, K. Karafasoulsi, D. Loukas and C. Lambropoulos, "Radioactive source localization by a two detector system," *Journal of Instrumentation,* vol. 10, no. 12, p. C12022, 21 December 2015.

[8] I. Kaissas, C. Papadimitropoulos, C. Potiriadis, K. Karafasoulis, D. Loukas and C. Lambropoulos, "Imaging of spatially extended hot spots with coded apertures for intra-operative nuclear medicine applications," *Journal of Instrumentation,* vol. 12, January 2017.

[9] D. Hatzistratis, G. Theodoratos, V. Zografos, I. Kazas, D. Loukas and C. Lambropoulos, "Hybrid Pixel Detectors for gamma/X-ray imaging," in *Journal of Physics: Conference Series*, 2015.

Summary of the CMS_INPP publications (2015-2016-2017)

Citation summary results	Citeable papers	Citeable papers excluding self cites	Citeable papers excluding RPP	Published only	Published only excluding self cites	Published only excluding RPP
Total number of papers analyzed:	317	317	317	300	300	300
Total number of citations:	17,859	10,331	17,859	17,766	10,271	17,766
Average citations per paper:	56.3	32.6	56.3	59.2	34.2	59.2
Breakdown of papers by citations:						
Renowned papers (500+)	3	2	3	3	2	3
Famous papers (250-499)	6	3	6	6	3	6
Very well-known papers (100-249)	28	9	28	28	9	28
Well-known papers (50-99)	64	33	64	64	33	64
Known papers (10-49)	166	163	166	165	162	165
Less known papers (1-9)	47	100	47	32	87	32
Unknown papers (0)	3	7	3	2	4	2
h_{HEP} index [?]	67	49	67	67	49	67

The ATLAS group of the Institute of Nuclear and Particle Physics (INPP_ATLAS), NCSR Demokritos

Personnel: **1) Theodoros GERALIS (Team representative)**
2) Georgios FANOURAKIS
3) Georgios STAVROPOULOS

The INPP_ATLAS group is a new group formed in 2017. On February 3, 2017 the group requested its admission in the ATLAS collaboration and was accepted as Associate Member on February 17, 2017 during the Collaboration Board (CB). An Expression of Interest (EoI) to become a full member of the ATLAS collaboration was submitted to the ATLAS spokesperson (Karl Jakobs) on June 14, 2017 and was presented in the ATLAS CB on June 24, 2017. The INPP_ATLAS group became full member during the ATLAS week CB in Bratislava in October 2017.
As agreed in the CB, areas the group is expected to contribute are:

- Taking over part of the NSW L1DDC and ADDC electronics card testing, including setup and development of the needed test benches;
- NSW Micromegas integration at CERN;
- Longterm maintenance for micromegas detectors and electronics after the NSW installation
- Provision and maintenance of monitoring/data quality software for the NSW

The INPP_ATLAS group became member of the Muon Project in the IB, August 2017.

INPP participated in the MAMMA (Muon ATLAS MicroMegas Activity) collaboration from the very beginning together with the groups of the National Technical University of Athens (NTUA), the University of Athens, the University of Thessaloniki, CEA Saclay and CERN. We have organized the beam tests at the Institute's Tandem accelerator and worked on the problem of discharges of the Micromegas detectors. The resistive Micromegas solution was further studied at the SPS/CERN beam tests in the framework of the MAMMA collaboration. We have produced common papers of those tests, four of which are listed at the end of this letter [1, 2, 3, 4]. In 2013 we have organized the VMM1 asic (Micromegas FE chip) neutron irradiation in order to study the SEUs. The work was performed under our supervision at INPP, over a period of six months for the firmware development and was part of a PhD thesis work. This study suggested the proper modifications to the VMM design in order to cope with the non negligible measured SEU rate [5].

Recently, the INPP_ATLAS group organized in collaboration with NTUA the neutron irradiation tests of the VMM3 and the other electronic cards in Tandem accelerator at INPP during two campaigns in May and in July 2017. Work also has started to install test bench setups.
Qualification work for G. Fanourakis, T. Geralis and G. Stavropoulos

In order to become authors of the ATLAS publications the members of the group, in agreement with the NSW project convener Stephanie Zimmerman, have undertaken specific tasks:

1) Build test bench setup for the ADDC cards testing, based on the VC707 Xilinx platform and connect to the Freibourg database for the logging of the massive testing (qualification of one person)
2) Build a DAQ slice: MMFE8 – L1DDC – VC709 – PC (specific), so called mini-Felix in the lines of the final Felix ATLAS version (qualification for two person

Conferences/Publications

[1] Performances of Anode-resistive Micromegas for HL-LHC. J. Manjarres et al. J. Manjarres, T. Alexopoulos, D. Attie, M.Boyer, J. Derre, G. Fanourakis, E. Ferrer-Ribas, J. Galan, E. Gazis, T. Geralis, A. Giganon, I. Giomataris, S. Herlant, F. Jeanneau, Ph. Schune, M. Titov, G. Tsipolitis, for the MAMMA Collaboration, JINST 7 (2012) C03040

[2] Performances and ageing study of resistive-anodes Micromegas detectors for HL-LHC environment. F. Jeanneau, et al. e-Print: arXiv:1201.1843

[3] Micromegas study for the sLHC environment. T. Alexopoulos, et al., JINST 5:P02003,2010,.

[4] Study of a micromegas chamber in a neutron beam. T. Alexopoulos, et al., JINST 5:P02005,2010,.

[5] Study of the VMM1 read-out chip in a neutron irradiation environment, T. Alexopoulos, G. Fanourakis, T. Geralis, M. Kokkoris, A. Kourkoumeli-Charalambidi, K. Papageorgiou, G. Tsipolitis, JINST 11 (2016) no.05, P05015.

The DAMA Instrumentation Laboratory

Personnel
Permanent staff: ***G. Fanourakis,***
T. Geralis
Post Docs (2015): ***D. Nikas***
A. Psallidas
PhD students (2105): A. Kalamaris
I. Kouris
Electronics engineer: Ch. Vassou
(2015)

The Data Acquisition Monitoring and Analysis (DAMA) instrumentation Laboratory aims at:

- Innovative R&D on Micro Pattern Gaseous Detectors - MPGDs
- Development of MPGD related electronics and DAQ systems
- Dedicated detectors for HEP, Nuclear Physics and applications

DAMA operates since 2000 and its main emphasis is the development of innovative MPGD and in particular Micromegas detectors.
DAMA was the first Laboratory to introduce the Micromegas technology in Greece (2001), promoted their use to the Greek academic community and initiated the most established to date biennial International Conference on MPGDs: "1st International Conference on Micro Pattern Gaseous Detectors - MPGD2009", Kolympari, Crete and was followed by MPGD2011, Kobe, Japan, MPGD2013, Zaragoza, Spain, MPGD2015, Trieste, Italy, MPGD2017, Philadelphia, USA and MPGD2019, La Rochelle, France.
Micro Pattern detectors can adapt to detect practically any kind of radiation: charged particle like cosmic muons, alphas, nuclei, neutrons, X-rays, visible photons and complement other types of detectors with their unique properties. A particular example is the measurement of the X-ray polarization at energies 1 – 10 keV, that can be performed thanks to the possibility for photoelectron tracking in the gas. This application can be used for X-ray polarimetry in Astronomy as well as in nuclear fusion as a tool to map the electric field in the core of the torus.

DAMA Infrastructure

The DAMA Laboratory is located in the ground floor of the INPP Tandem building and occupies an area of about 60 m^2. The main infrastructure is shown below: 1) Three fully equipped test benches for studying MPGDs: Gas distribution, Electronics Racks with NIM modules, HV modules, preamplifiers, amplifiers etc, Oscilloscopes, Workstations, Radioactive sources, 2) Gas Mixer and distribution of premixed gases, 3) Electronics and DAQ systems: VME Data Acquisition (CAEN controller, optical fiber connection, CRAMS, sequencer, ADC unit, Gate generator, etc), SRS - Scalable Readout System (APV FE, 2000 channels readout), FEMINOS readout for TPC mode, Electronics: Racks (1 VME and 4 NIM crates), NIM units, (Multifunction NIM modules, Amplifiers, Discrim., HV, LV PS Pulse generators, NIM/ TTL/ NIM converter etc), MCAs (2), Preamps, 4) Design packages: Electronics design packages, Finite Element Analysis, DAQ software (Labview, C++), FPGA (Altera, Xilinx) design workstations, FPGA Design platforms.

5) Clean room: 12 m² – two rooms Class 10,000 and Class 100,000, Microscope

DAMA Current Research Activities

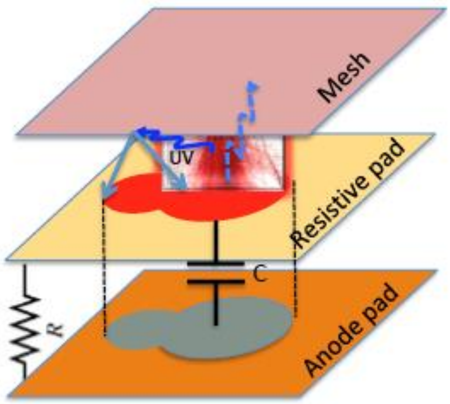
The main activity of the DAMA Laboratory is currently within the ATLAS collaboration and it is described in the beginning of this session.

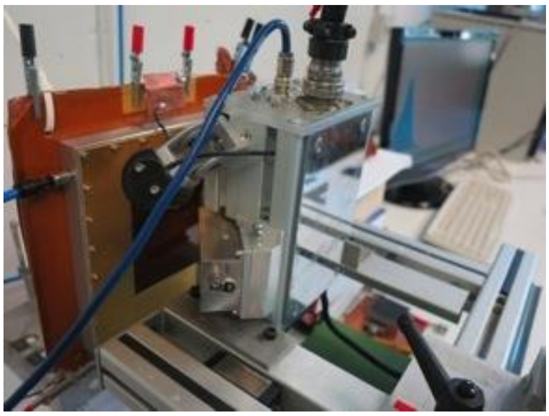
Ongoing R&D activities are performed on highly promising developments.

A) Resistive Bulk Micromegas for High Rate applications
Collaboration: NCSR Demokritos, LAPP Annecy, CEA Saclay

Detector operation at very high rates is required by experiments in future accelerators like the High Luminosity LHC (HL-LHC), the International Linear Colliders (ILC) or in the Future Circular Collider (FCC). They can be used in high granularity Particle Flow (PF) hadron calorimeters with small thickness at ultra high rates thanks to their discharge quenching. They are also good candidates for operation at high eta at the HL-LHC where they can withstand rates of 10s of MHz/cm^2.

Our R&D has proven the excellent linearity for the buried resistor technique as well as their excellent behavior concerning spark quenching. The figure shows the model of the buried resistor technique. The photo shows the irradiation setup in DAMA Lab for the linearity tests of the detector.





Further development is performed in the frame of the RD51 Common Fund project "Sampling Calorimetry with Resistive Anode MPGDs" – SCREAM. It is a collaboration of six institutions: LAPP Annecy, Weizmann Institute of Science, INPP/NCSR Demokritos, CEA/IRFU Saclay, University of Aveiro and University of Coimbra aiming to develop MPGD technologies appropriate for hadron sampling calorimeters for the ILC but will also provide valuable tests for the operation of MPGDs at very high rates.

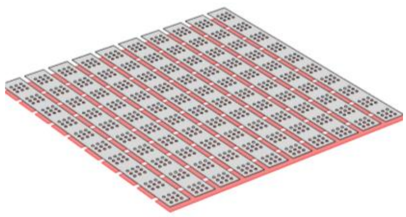
Conferences/Publications

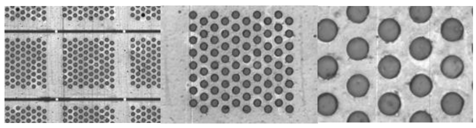
- *M. Chefdeville et al., Test in a beam of large area Micromegas chambers for sampling calorimetry, NIMA 763 (2014) 221231.*
- *M. Chefdeville, T. Geralis, M. Titov, Resistive Micromegas for sampling calorimetry, a study of space charge effect, Proceedings of Elba proceedings, Nucl.Instrum.Meth. A824(2016) 510-511.*
- *Resistive Micromegas for sampling calorimetry, a study of charge-up effects M. Chefdeville, Y. Karyotakis, T. Geralis, M. Titov. 2016. 2 pp. Published in Nucl.Instrum.Meth. A824 (2016) 510-511*
- *T. Geralis et al., 'Development of resistive anode Micromegas for sampling calorimetry', Proceedings of the MPGD2015 conference in EPJ Web of Conf., 174, 01017 (2018).*

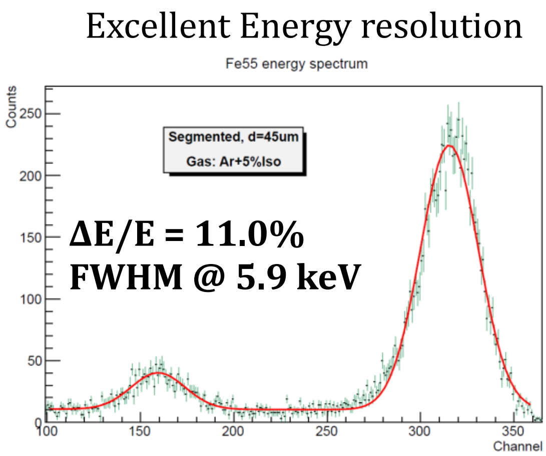
B) Real x-y Segmented Mesh Microbulk Micromegas

Collaboration of INPP/NCSR Demokritos, CEA/IRFY Saclay, University of Zaragoza and CERN.

The Aim of the project is to develop microbulk Micromegas detectors with real x-y structure by segmenting the mesh. The old fashioned way to provide x and y information was a complicated pcb structure with pads on the anode surface and through metalized holes in order to form conductive y strips on a layer beneath the anode. The manufacturing procedure was difficult and fragile with the disadvantage of higher material budget. The new manufacturing process is simpler and leads to mass minimization, which is adequate for rare searches applications but also for neutron beam profilers. Our group proposed and coordinated the effort on the optimization and the design of the Real x-y segmented mesh microbulk Micromegas, which was supported by the RD51 Common Fund.

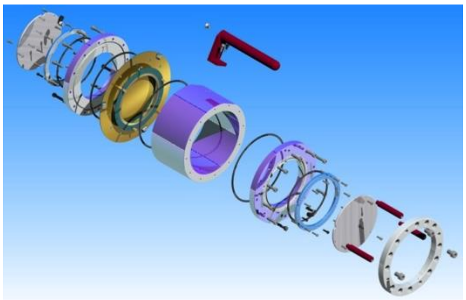
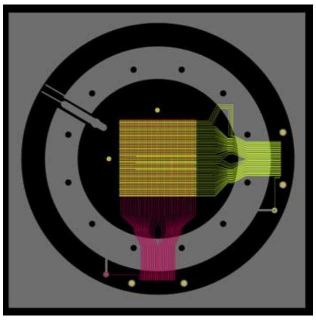






The performance for the energy resolution is impressive and reaches an optimum for a gaseous detector of 11% FWHM at 5.9 keV (see figure).

Real x-y segmented mesh microbulk Micromegas is very adequate for Rare searches like axion or dark matter thanks to the very low background that can be achieved (~ 10^{-7} cnts/keV/cm^2/s) with its low material budget and additional measures like, low radioactivity shielding, cosmic veto etc.

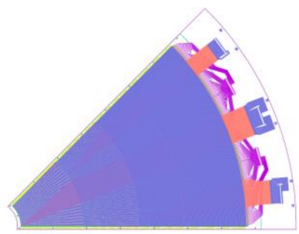
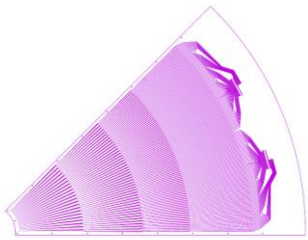
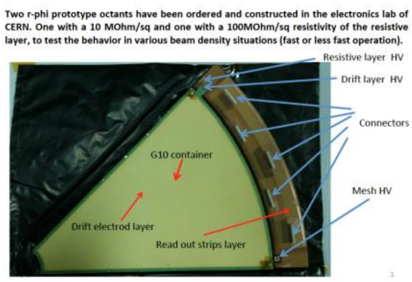
It is already used in the nTOF collaboration for a neutron beam profiler with excellent results. This is the thinnest neutron detector ever manufactured with only 5 μm + 5 μm of Cu and the remaining polyimide in betwwen the x and y foils.

Conferences/Publications

- *T. Geralis et al. 'A real x-y Microbulk Micromegas with segmented mesh', PoS (TIPP2014)055.*
- *M. Diakaki et al., 'A novel segmented mesh Micromegas detector development for neutron beam profiling', Submitted to NIMA.*

C) The r-ϕ Micromegas

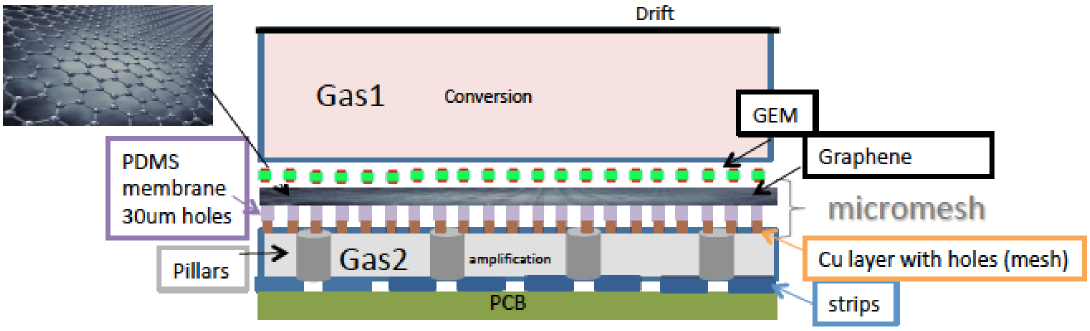
The r-ϕ Micromegas is with resistive surface especially designed to operate in cylindrical geometry like in the srEDM experiment or the high eta rings at the HL-LHC.

This design is made by the INPP group and first prototypes are produced (see photo) and tested in beams at CERN.

D) Micromegas Using micro fabrication Techniques and Graphene
Collaboration: INPP/NCSR Demokritos, INN/NCSR Demokritos

Our primary goal and ambition is to build a Micromegas detector operating with two different gases in the conversion volume and the amplification volume. This idea and the progress towards this goal was presented by our group for a first time at the MPGD2015 in Trieste. Two-gas phase detector separated by a Graphene layer will exploit differences in gas properties to improve performance. We are studying the electron transparency together with the elimination of the gas atoms or ions transparency through graphene.



Conferences/Publications

1) *T. Geralis et al. 'Innovative Micromegas manufacturing with micro-fabrication techniques and use of graphene', oral presentation in MPGD2015, 12 – 15 October 2015, Trieste, Italy*

Theoretical High Energy Physics

Theory Group

Permanent Staff: M. Axenides (Director of Research. , Theoretical Particle & Astroparticle Physics)

C. Papadopoulos (Director of Research. , Theoretical Particle Physics)

G. Savvidy (Director of Research , Theoretical Particle Physics)

Postdoctoral Research Associates: H. Frellesvig, G. Georgiou, S. Konitopoulos, G. Linardopoulos, G. Pastras, D. Tommasini, C. Wever.

Visiting Scientists: M. Kalomenopoulos, K. Karamanos, R. Poghosyan, K. Savvidy

Adjunct Scientists: E. Floratos (U. of Athens)

PhD students: D. Katsinis, H.Poghosyan, N.Syrrakos

Research directions. The fundamental forces of Nature the electromagnetic, weak and strong interactions are successfully described by the non-Abelian fields. In that description the photon, W-bosons and gluons mediate interaction between smallest constituents of matter - leptons and quarks. The main objectives of the High Energy Theory Group is the exploration of the physics described by the **STANDARD MODEL of FUNDAMENTAL FORCES** and **PHYSICS BEYOND the SM at LHC at CERN.** This includes super-symmetric extensions, string theory extensions, search of higher space-time dimensions, the origin of the inertial mass, problems at the interface of particle physics and cosmology, such as inflation, baryogenesis, dark energy and matter.

The project in Gauge and String theories aims to study the interaction of matter, which carries not only internal charges, but also arbitrary high spins. This extension leads to a theory in which fundamental forces are mediated by integer-spin gauge quanta and the photon, W-bosons and gluons become members of a bigger family of tensor gauge bosons. A new topological mechanism of mass generation is possible in this extension. These predictions can be tested at LHC.

The project in Particle Physics and Cosmology aims to study problems at the interface of particle physics and cosmology, such as inflation, baryogenesis, dark energy and matter, the microwave background anisotropies. Grand unified theories admit in their spectrum vortices and q-balls whose dynamics in the early universe contribute to baryogenesis. We explore their properties and cosmic consequences.

The project in High Energy Physics Phenomenology and Computational Physics aims to develop innovative methods and algorithms in order to establish an efficient framework for higher order corrections for multi-particle processes, including a) amplitude reduction at the integrand level beyond one-loop, b) the evaluation of multi-loop Master Integrals and c) the application of the above-mentioned techniques to scattering processes at the LHC and beyond.

The project on Non-linear Chaotic Dynamics and Complex Systems involves both research and teaching. It pertains to the interplay between chaotic dynamics and fundamental interactions. Noteworthy results have been the observation of chaos in Yang Mills theories such as QCD as well as more recently in matrix and membrane dynamics of M-theory. Moreover the principles of chaos have been successfully shown to give rise to novel random number generator algorithms (MIX-MAX) with which to make Monte-Carlo Simulations in high energy elementary particle experiments such as the LHC.
Demokritos has been the hub of the national network of Complex Systems COSA-NaNet which organizes regular seminars on Nonlinear Chaotic Dynamics and Complexity along with a graduate level course on "Special topics on Complex Systems and Applications" in association with the National Technical University of Athens.

The MixMax project

The primary objective of the MIXMAX project (2015-2018; H2020-MSCA-RISE-MIXMAX) was a systematic development of the state of the art new generation of Pseudo Random Number Generators based on Kolmogorov-Anosov C-K systems, which demonstrates excellent statistical properties, into a multidisciplinary usable product. This innovative class of RNG was proposed earlier by G. Savvidy in 1986 and by the members of the network and relies on the fundamental discoveries and results of Ergodic theory. It has been recently tested in many platforms and is evaluated as random number generator in the CMS simulation program. The MixMax generator is now included in:

a) ROOT (https://root.cern.ch/doc/master/classTRandom.html),
b) Geant4/CLHEP as default generator (https://gitlab.cern.ch/CLHEP/CLHEP/blob/develop/ChangeLog) MixMax was set as default engine since release 2.4.0.0 deployed on November 2017, and in Geant4 since release 10.3.
c) PYTHIA (http://home.thep.lu.se/~torbjorn/doxygen/MixMax_8h_source.html)
d) GSL - GNU Scientific Library, the Extensions/Applications (https://www.gnu.org/software/gsl/)
e) CMS as default generator (https://indico.cern.ch/event/731433/contributions/3015654/attachments/1680131/2698971/CMSsim.pdf page 13 , https://indico.cern.ch/event/587955/contributions/2937635/attachments/1679273/2706817/PosterCMS_SIM_v4.pdf)

Publications by the theoretical group: 65 publications in refereed journals and conference proceedings in the last three years 2015-2017 and about 375 citations for these publications (13,410 citations for the three permanent staff, H-index 52).

Conferences: international workshops and conferences have been organized in Greece and in Europe.

Grants: 6 EU and national grants have been obtained by the theoretical group.

Teaching: the group offers courses in quantum field theory for graduate and undergraduate students from Polytechnic University and Demokritos Center, training of graduate students for advanced degrees. Seminars and lectures in summer schools organized by Demokritos for university undergraduate students

1. Classical limit theorems and high entropy MIXMAX random number generator
Hayk Poghosyan (Democritos Nucl. Res. Ctr. & Yerevan State U.), Konstantin Savvidy, George Savvidy (Democritos Nucl. Res. Ctr.). Jul 31, 2017. 15 pp. NRCPS-HE-74-2017
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NCSR-HE-2017-66
e-Print: arXiv:1705.09913 [hep-th]

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George Savvidy, Konstantin Savvidy (Democritos Nucl. Res. Ctr.). Feb 12, 2017. 19 pp.
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Spyros Konitopoulos, George Savvidy (Democritos Nucl. Res. Ctr.). 2016. 17 pp.
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Damiano Tommasini, Hjalte Frellesvig, Costas Papadopoulos (Democritos Nucl. Res. Ctr.), Christopher Wever (Democritos Nucl. Res. Ctr. & KIT, Karlsruhe, TTP & KIT, Karlsruhe, IKP). 2016. 10 pp.
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Georgios Pastras (Democritos Nucl. Res. Ctr.). Dec 12, 2016. 47 pp.
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36. Four Lectures on Weierstrass Elliptic Function and Applications in Classical and Quantum Mechanics
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Georgios Pastras (Democritos Nucl. Res. Ctr.). Oct 5, 2017. 19 pp.
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DOI: 10.1002/prop.201700090
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38. An Inverse Mass Expansion for Entanglement Entropy in Free Massive Scalar Field Theory
Dimitrios Katsinis (Democritos Nucl. Res. Ctr. & Athens Natl. Capodistrian U.), Georgios Pastras (Democritos Nucl. Res. Ctr.). Nov 7, 2017. 18 pp.
Published in Eur.Phys.J. C78 (2018) no.4, 282
DOI: 10.1140/epjc/s10052-018-5596-4
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Minos Axenides (Democritos Nucl. Res. Ctr.), Emmanuel Floratos (Democritos Nucl. Res. Ctr. & Athens U.), Stam Nicolis (Fed. Denis Poisson, Tours). Aug 28, 2016. 32 pp.
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E.G. Floratos (CERN & Athens U.), G.K. Leontaris (Ioannina U.). Nov 5, 2015. 7 pp.
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Publication: Chaos, Solitons & Fractals, vol. 96, pp. 154-159
Publication Date: 03/2017 ● Georgios Fotinos Prize 2017 (Academy of Athens)

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65. Entropy Production of Entirely Diffusional Laplacian Transfer and the Possible Role of Fragmentation of the Boundaries
Authors: Karamanos, K.; Mistakidis, S. I.; Massart, T. J.; Mistakidis, I. S.
Publication: Fractals, Volume 23, Issue 3, id. 1550026
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Experimental Nuclear Physics & Applications

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Scientific program

The scientific program in Experimental Nuclear Physics & Ion-Beam Applications is implemented at the in-house TANDEM Accelerator Laboratory (TAL) as well as at various European laboratories. As such, the activities presented separately, in the section reporting on the TANDEM Accelerator Laboratory, were performed by the same team that implements the scientific program presented here. In brief, the former activities refer to the upgrades carried out at the in-house accelerator, the installation of new instruments and setups, as well as training and outreach. All other research and dissemination activities of the group are presented below.

The main group activities include systematic studies of nuclear reactions relevant to nuclear astrophysics and the application of ion-beam analysis (IBA) techniques aiming either at the elemental analysis of material surfaces or the study of irradiated materials with technological interest, such as those related to the energy production via fusion. In parallel, the group is active in the field of nuclear structure studies with experiments performed jointly with national and European research teams.

The Nuclear Astrophysics program is described in details in the recent review paper by S. Harissopulos published in a peer-reviewed topical issue[2]. In brief, the Nuclear Astrophysics activities of the group focus on the study of nuclear capture reactions relevant to the understanding of a nucleosynthetic mechanism occurring in certain explosive stellar environments, such as supernovae. This mechanism, termed *p-process*[3], is responsible for the synthesis of certain 35 neutron-deficient nuclei heavier than iron that lie "north-west" of the stability valley, between ^{74}Se and ^{196}Hg. These nuclides are known as the *p-nuclei* and have, so far, been observed only in the solar system.

To date, all p-process nucleosynthesis models are able to reproduce most of the solar p-nuclei abundances within a factor of 3 but fail in the case of the light p-nuclei. The observed discrepancies could result due to uncertainties in the purely astrophysics modeling of the p-process. However, on top of any astrophysical model improvements, it is imperative that the nuclear physics uncertainties entering the astrophysical calculations are reduced or set under control at least. Given this challenge, the main goal of Nuclear Astrophysics program is to shed light on nuclear physics aspects of the p-process puzzle that still remain diffuse and contribute, this way, to the understanding of the observed discrepancies of the p-nuclei abundances in the solar-system abundances.

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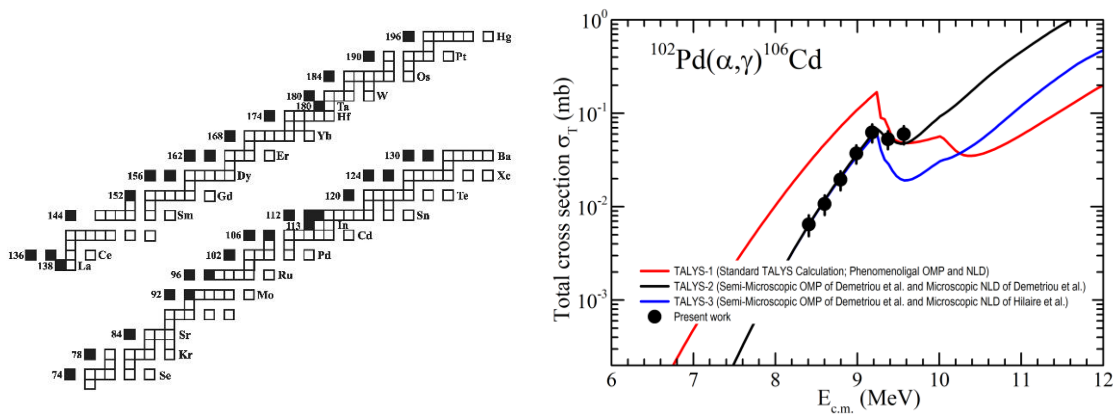
[2] See: S. V. Harissopulos, Eur. Phys. J. Plus 133, 332 (2018); https://doi.org/10.1140/epjp/i2018-12185-8
[3] M. Arnould and S. Goriely, Physics Reports 384, 1 (2003)

Indeed, in addition to the uncertainties of pure astrophysics nature, nuclear uncertainties also need to be considered since astrophysical abundance calculations make an extensive use of the nuclear statistical model for the calculation of the reaction rates of an extended reaction network of more than 20000 reactions involving almost 2000 nuclei heavier than iron. In addition, the vast majority of these reactions involves unstable target nuclei far off stability that are hardly reachable, even with the latest developments in the production and acceleration of unstable ion beams.

Under these conditions, the major research objectives of the Nuclear Astrophysics program of INPP are two: The first one, required to achieve the overall goal of the program, is the establishment of a proper cross-section database. For this purpose, systematic cross-section measurements of proton and α-particle capture reactions in medium-mass nuclei, from Cu to Cs, are performed. The second objective is implemented in collaboration with Dr. P. Demetriou, Principal Researcher of INPP (currently on special leave of absence at the IAEA, Vienna, Austria), who is using the experimental data measured by the group to develop microscopic models of α-particle-nucleus optical-model potentials (αOMP) for compound-nucleus reactions and perform credibility tests of existing phenomenological ones.

Cross sections are measured[4] by the group either from γ-angular distributions or from angle-integrated γ-ray yields. In the former case, one measures the angular distributions of the γ transitions depopulating highly excited states of the compound nucleus produced in a capture reaction. The latter method, coined 4π γ-summing technique, was previously developed by our group and enables us to study capture reactions within relatively short beam times. It was first realized at the INPP Tandem Accelerator by employing a large-volume eightfold segmented cylindrically-shaped NaI(Tl) crystal. Meanwhile, the method has been considerably improved by utilizing a 12inch×12inch single NaI(Tl) crystal installed at the accelerator of the Ruhr-University Bochum, Germany. Thanks to an EC/FP7 Grant with the acronym LIBRA, a state-of-the art 14inch×14inch NaI(Tl) crystal with superior absolute efficiency was purchased and was recently installed at the Tandem accelerator. This 4π γ-calorimeter is described in the section reporting on the TANDEM Accelerator Laboratory.



Left: The 35 p-nuclei.
Right: Comparison of measured (α,γ) cross sections for the p-nucleus ^{102}Pd with the predictions of statistical model calculations using either phenomenological (red curve) or microscopic Optical Model Potentials (OMP) and Nuclear Level Densities (NLD)

[4] See: S. V. Harissopulos, Eur. Phys. J. Plus 133, 332 (2018); https://doi.org/10.1140/epjp/i2018-12185-8

Having already measured more than 20 proton and alpha-particle capture reactions, the following conclusions can be drawn: In the case of (p,γ) reactions, uncertainties in the OMPs and NLDs affecting statistical model calculations (OMP, NLD) give rise to at most 30-40% uncertainties in the astrophysical reaction rates. Moreover, the Hauser-Feshbach (HF) predictions are more sensitive to OMP rather than to NLD. The α-particle-nucleus Optical Model Potential is still poorly known. Consequently, the astrophysical (α,γ) reaction rates obtained from HF calculations can be highly uncertain and abundance calculations may strongly be affected. So far, the α-potential of Demetriou *et al.*[5] and its recent improvements reproduces well new experimental data. However, more data are needed in the mass range A≈100 to further constrain the potential parameters.

The Nuclear Astrophysics program of our group was complemented with investigations of pygmy resonances, nuclear level density and γ-ray strength determinations performed in collaboration with European groups from Cologne, Germany and Oslo, Norway. These activities are relevant for the study of either the p-process or the r-process[6].

The Nuclear Structure studies of the group are carried out jointly with collaborators in Europe. In this context, our group has been seeking for experimental evidence of the critical point symmetries E(5) and X(5) introduced by F. Iachello. E(5) symmetry describes the phase shape transition between a spherical harmonic vibrator to that of a "γ-soft" rotor, while X(5) between a prolate-deformed symmetric rotor and a spherical harmonic vibrator. As in the case of the symmetries introduced by the Interacting Boson Approximation (IBA) model, critical-point symmetries provide parameter-free predictions for excitation energies and their ratios, as well as for reduced transition probabilities. While the X(5) critical point is quite well established with nuclei that exhibit X(5) features in both excitation energy and transition probabilities, this is not the case for the E(5) critical point. Nuclei have been proposed as possible E(5) candidates mainly due to their excitation energies, but in most cases the experimental data are scarce and the verification is not conclusive. These activities were performed within wide European Collaborations at large-scale facilities abroad.

Within national collaborations, primarily with the National Technical University of Athens (NTUA) and the University of Ioannina (UoI), the group has carried out at the local Tandem accelerator activation measurements of cross sections of (n,xn) and (n,f) reactions. A good part of these activities are related to the research program of CERN's n_TOF collaboration. The data are important for the design of Accelerator Driven Systems (ADS) for the future production of clean and safe nuclear energy as well as for the incineration of nuclear waste. These measurements included the ^{241}Am(n,2n) and the ^{236}U(n,f) reactions, with the latter one being implemented for the first time using a gaseous MicroMegas detector.

Ion-Beam Applications: During years 2015-2017, the group continued its activities in basic and applied research topics related with the interaction of light ions with matter. The research was focused on the measurement of differential cross sections of proton and deuteron induced nuclear reactions at energies and angles suitable for Ion Beam Analysis techniques. These techniques are used in a broad range of applications, including microelectronics, cultural heritage studies, biology and material science.

Particle Induced Gamma-ray Emission (PIGE) is as a sub-category of Nuclear Reaction Analysis, in the case when characteristic prompt γ-rays are detected as reaction products.

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[5] P. Demetriou *et al.*, Nuclear Physics A707, 142 (2002)
[6] M. Arnould, S. Goriely and K. Takahashi, Physics Reports 450, 97 (2007)

This technique has been used since the early 1960's for various applications. The potential of this technique for depth profiling, with better resolution than the other IBA techniques, was soon recognized. The basic physical processes underlying PIGE are now well understood, but the reliability of analytical results is again limited by knowledge of the physical data, namely ion stopping power values and – mainly – differential cross sections. In this context, the group has measured the differential cross sections of the ^{10}B, ^{11}B and ^{25}Mg (p,p'γ) reactions using the gamma-ray angular distribution turntable that was recently installed at the Tandem accelerator. Moreover, the group helped in the dissemination and improvement of the application of the PIGE technique by participating in the Coordinated Research Program, entitled "Development of a Reference Database for Particle-Induced Gamma-ray Emission" initiated by IAEA.

EBS, through the detection of elastically charged particles can, in principle, provide information concerning the light isotopes' concentration and depth profile distribution. However, its applicability is hindered by the lack of suitable cross section data, as well as, the proper validation of the existing ones. Towards this goal, the group has measured, in collaboration with the groups of the National Technical University of Athens and of the University of Ioannina, the differential cross section of the ^{19}F(d, d0) reaction. In addition, the evaluated proton differential cross sections of ^{nat}Si and ^{16}O suitable for EBS analysis were benchmarked.

The Joint European Torus (JET) tokamak, the largest controlled fusion device with magnetic confinement in the world, investigates the potential of fusion power as a future energy source. Its main scientific mission is to develop plasma operation scenarios for a reactor-class machine such as the International Thermonuclear Experimental Reactor (ITER). This includes also the performance test of plasma-facing materials (PFM) and components (PFC). Fuel retention and material migration are among the main consequences of plasma impact on PFM. A comprehensive understanding of these mechanisms is crucial for the safe operation of a fusion reactor. Previous results, from ex-situ analysis of tiles from JET, proved that one of the most efficient methods for the characterization of PFC surfaces can be achieved by Ion Beam Analysis (IBA) techniques, due to their improved sensitivity. The aim is to provide the fusion scientific community with information regarding the erosion, deposition and migration mechanisms of materials to be used in the future fusion devices. A set of ion beam techniques on a number of selected tiles from the ITER-Like wall configuration of JET (JET–ILW) was performed aiming at determining the light and heavier elements concentrations present on their surface.

Last but not least, the Experimental Nuclear Physics & Applications Group of INPP has supported all external users of the Tandem accelerator in preparing and running their experiments at the accelerator.

Scientific Outputs

PEER-REVIEWED PUBLICATIONS

1. Study of the ^{10}B(p,αγ)^{7}Be and ^{10}B(p,p'γ)^{10}B reactions for PIGE purposes, by A. Lagoyannis, K. Preketes-Sigalas, M. Axiotis, V. Foteinou, S. Harissopulos, M. Kokkoris, P. Misaelides, V. Paneta, N. Patronis, in Nuclear Instr. and Methods in Physics Research B 342, 271 (2015). [http://dx.doi.org/10.1016/j.nimb.2014.10.021]

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18. PIGE related differential cross-section measurements of the $^{25}Mg(p,p'\gamma)^{25}Mg$ reaction, by K. Preketes-Sigalas, A. Lagoyannis, M. Axiotis, H.W. Becker, V. Foteinou, S. Harissopulos, M. Kokkoris, G. Provatas, in Nuclear Instr. and Methods in Physics Research B 386, 4 (2016). [https://doi.org/10.1016/j.nimb.2016.08.020]

19. Differential cross section measurements of the $^{19}F(d,d_0)$ elastic scattering for Ion Beam Analysis purposes, by V. Foteinou, G. Provatas, X. Aslanoglou, M. Axiotis, S. Harissopulos, M. Kokkoris, A. Lagoyannis, P. Misaelides, E. Ntemou, N. Patronis, K. Preketes-Sigalas, in Nuclear Instruments and Methods in Physics Research B 396, 1 (2017) [http://dx.doi.org/10.1016/j.nimb.2017.01.087]

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22. Surface composition and structure of divertor tiles following the JET tokamak operation with the ITER-like wall, by A. Lagoyannis, P. Tsavalas, K. Mergia, G. Provatas, K. Triantou,

E. Tsompopoulou, M. Rubel, P. Petersson, A. Widdowson, S. Harissopulos, T.J. Mertzimekis, and the JET contributors, in Nuclear Fusion 57, 076027 (2017). [https://doi.org/10.1088/1741-4326/aa6ec1]

23. Dissolution and Sorption Processes on the Surface of Calcite in the Presence of High Co^{2+} Concentration, by J. González-López, Á. Fernández-González, A. Jiménez, A. Godelitsas, S. Ladas, G. Provatas, A. Lagogiannis, I. N. Pasias, N. S. Thomaidis and M. Prieto in Minerals 7, 23 (2017). [https://doi.org/10.3390/min7020023]

24. Benchmarking the evaluated proton differential cross sections suitable for the EBS analysis of ^{nat}Si and ^{16}O, by M. Kokkoris, S. Dede, K. Kantre, A. Lagoyannis, E. Ntemou, V. Paneta, K. Preketes-Sigalas, G. Provatas, R. Vlastou, I. Bogdanović-Radović, Z.Siketić, N.Obajdin, in Nuclear Instruments and Methods in Physics Research B 405, 50 (2017). [https://doi.org/10.1016/j.nimb.2017.05.021]

25. Lifetimes and electromagnetic transition strengths in ^{157}Dy, by K. A. Gladnishki, P. Petkov, O. Möller, A. Dewald, J. Jolie, D. Tonev, M. Trichkova, S. Heinze, P. von Brentano, D. Bazzacco, C. A. Ur, E. Farnea, M. Axiotis, S. Lunardi, G. de Angelis, D. R. Napoli, N. Marginean, T. Martinez, M. A. Caprio, and G. Rainovski, in Physical Review C 96, 024324 (2017). [https://doi.org/10.1103/PhysRevC.96.024324]

26. Differential cross-section measurements for deuteron elastic scattering on ^{nat}N, suitable for EBS, by M. Kokkoris, X. Aslanoglou, M. Axiotis, A. Lagoyannis, P. Misaelides, E. Ntemou, N. Patronis, K. Preketes-Sigalas, P. Tsintaria, in Nuclear Instruments and Methods in Physics Research B 410, 29 (2017). [https://doi.org/10.1016/j.nimb.2017.08.004]

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CONFERENCE PROCEEDINGS

1. Atomic Physics with Accelerators: Projectile Electron Spectroscopy (APAPES), by I. Madesis, A. Dimitriou, A. Laoutaris, A. Lagoyannis, M. Axiotis, T. Mertzimekis, M. Andrianis, S. Harissopulos, E. P. Benis, B. Sulik, I. Valastyán and T. J. M. Zouros; 17th International Conference on the Physics of Highly Charged Ions; in Journal of Physics: Conference Series 583, 012014 (2015); [http://dx.doi.org/10.1088/1742-6596/583/1/012014]

2. Enhanced low-energy γ-decay probability - Implications for r-process (n; γ) reaction rates, By A. C Larsen, M. Guttormsen, F. L Bello Garrotte, L. A Bernstein, D. L Bleuel, A. Bracco, B. A Brown, F. Camera, L. Crespo Campo, S. Frauendorf, B. L Goldblum, S. Goriely, A. Görgen, K. Hadynska-Klek, T. W. Hagen, S. Harissopulos, B. V Kheswa, M. Klintefjord, S. Leoni, S. N Liddick, F. Naqvi, G. Perdikakis, T. Renstrøm, A. M Rogers, S. J Rose, E. Sahin, R. Schwengner, S. Siem, and A. Simon, in Proceedings of the 14th International Conference on Nuclear Reaction Mechanisms, NRM 2015, Villa Monastero, Varenna; Italy; 15-19 June 2015. (Eds. F. Cerutti, M; Chadwick, A. Ferrari, T. Kawano, P. Schoof); Imprint: CERN Proceedings; 01/2015, Pages 271-276; [https://cds.cern.ch/record/2114737?ln=en]

3. Use of Gas and Foil strippers for the production of He-like ionic beams in both pure ground state ($1s^2$) and mixed states ($1s^2$, 1s2s) for zero-degree Auger Projectile Electron Spectroscopy,

by A. Laoutaris, I. Madesis, A. Dimitriou, A. Lagoyannis, M. Axiotis, E. P. Benis, T.J.M. Zouros; XXIX International Conference on Photonic, Electronic, and Atomic Collisions (ICPEAC 2015); in Journal of Physics: Conference Series 635, 052062 (2015); [http://dx.doi.org/10.1088/1742-6596/635/5/052062]

4. Study of (n,2n) reaction on ^{191,193}Ir isotopes and isomeric cross section ratios, by R. Vlastou, A. Kalamara, M. Kokkoris, N. Patronis, M. Serris, M. Georgoulakis, S. Hassapoglou, K. Kobothanasis, M. Axiotis and A. Lagoyannis; ND 2016: International Conference on Nuclear Data for Science and Technology, Bruges; Belgium; 11-16 September 2016; in EPJ Web of Conferences 146, 11013 (2017); [https://doi.org/10.1051/epjconf/201714611013].

5. Neutron-induced fission cross-section measurement of ^{234}U with quasi-monoenergetic beams in the keV and MeV range using micromegas detectors, by A. Tsinganis, M. Kokkoris, R. Vlastou, A. Kalamara, A. Stamatopoulos, A. Kanellakopoulos, A. Lagoyannis and M. Axiotis; ND 2016: International Conference on Nuclear Data for Science and Technology, Bruges; Belgium; 11-16 September 2016; in EPJ Web of Conferences 146, 04035 (2017). [https://doi.org/10.1051/epjconf/201714604035]

6. Cross section of the ^{197}Au(n,2n)^{196}Au reaction, by A. Kalamara, R. Vlastou, M. Kokkoris, M. Diakaki, M. Serris, N. Patronis, M. Axiotis and A. Lagoyannis; ND 2016: International Conference on Nuclear Data for Science and Technology, Bruges; Belgium; 11-16 Sept. 2016; EPJ Web of Conferences 146, 11048 (2017); https://doi.org/10.1051/epjconf/201714611048

In addition, more than 10 additional articles have been published in the Proceedings of the Annual Symposia of the Hellenic Nuclear Physics Society (HNPS)[7].

Theses Supervision

(all theses submitted to the School of Applied Physics and Mathematics of the NTUA)

PhD theses

- V. Paneta: "Study of differential cross sections suitable for EBS and NRA"; 2015

MSc theses

- G. Maragouli: "Study of the neutron flux using the ^{2}H(d,n)^{3}He reaction"; 2015
- K. Preketes-Sigalas: "Study of the ^{10}B(p,αγ)^{7}Be and ^{10}B(p,p'γ)^{10}B reactions for PIGE purposes"; 2015
- V. Lagaki: "Measurement of proton capture cross sections of Sr isotopes using a gamma-calorimeter at astrophysical relevant energies"; 2016
- V. Mixalopoulou-Petropoulou: "Measurement of proton capture reactions at medium-heavy nuclei by differential cross section integration"; 2016
- E. Ntemou: "Study of the differential cross section of elastic scattering ^{6}Li(d,d_0) for analytical purposes"; 2017.

Diploma theses

- S. Dede: "Benchmarking differential cross sections of light elements suitable for EBS"; 2016
- P. Tsintari: "Study of deuteron elastic differential cross sections on nitrogen suitable for EBS"; 2017

[7] http://radium.phys.uoa.gr/HNPS/

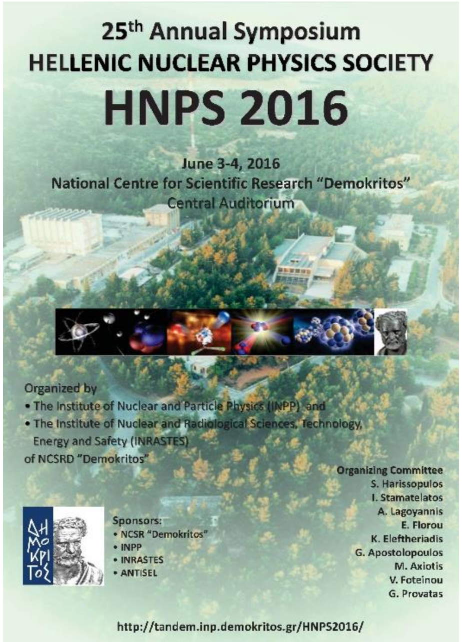
ORGANIZATION OF SCIENTIFIC AND OUTREACH EVENTS

- **July 1, 2015:** Workshop entitled "**Accelerator Technologies for Society**" focusing on the applications of modern accelerating systems in health (cancer treatment with protons, radioisotopes for new radiopharmaceuticals), the environment and the development of new innovative materials. It was organized as part of the "3rd Hellenic Forum for Science, Technology and Innovation" of the NCSR "Demokritos". Details: http://events.demokritos.gr/HF2015/?session=accelerator-technologies-for-society.

- **March 13-14, 2015:** Organization of the 82nd Meeting of the Nuclear Physics European Collaboration Committee – NuPECC (an expert committee of the European Science Foundation involving almost all European Countries). The meeting included a mini workshop on the activities of the Greek Nuclear Physics Community. Colleagues from all of the country's Universities and Research Centers were invited. The presentations are given in http://www.nupecc.org/index.php?display=presentations/talks

- **May 12, 2016**: Special event for the public entitled "**Star Cooking after the third minute of Genesis**" (Αστρομαγειρέματα μετά το 3^{ο} λεπτό της Δημιουργίας); jointly organized with the "Cafe Scientifique Athens" at the library building of "Demokritos". The event included a public lecture followed by a guided tour at the Tandem accelerator. It was attended by more than 200 people. Details about the event together with a video of the lecture can be found in the listing at the website of Cafe Scientifique: http://www.cafescientifique.org/index.php?option=com_contentbuilder&title=europe-scandinavia-athens&controller=details&id=1&record_id=220&Itemid=494&limitstart=0&filter_order and in https://www.facebook.com/CafeSci.gr/photos/a.331790850266359/848747968570642/?type=3&theater

- **June 3-4, 2016: 25th Symposium of the Hellenic Nuclear Physics Society**, Demokritos, Athens, Greece, jointly organized with the Institute of Nuclear and Radiological Sciences, Energy, Technology and Safety of NCSR "Demokritos". Details in: http://tandem.inp.demokritos.gr/HNPS2016/



Invited Talks In Scientific Meetings – Invited Seminars

- p-process workshop 2015: status and outlook, Limassol, Cyprus, June 10 - 13, 2015; S. Harissopulos: "An overview of nuclear physics experiments aiming at solving the p-process puzzle"; http://exp-astro.physik.uni-frankfurt.de/meetings/pProcessWorkshop2015/talks.php

- ND2016 – International Conference on Nuclear Data for Science and Technology, Bruges, Belgium, Sept. 11-16, 2016; S. Harissopulos: "Radiative capture reactions for the p process"

- Invited seminar given at the Division of Nuclear and Elementary Particle Physics of the Dept. of Physics of the Aristotle University of Thessaloniki, Greece, April 1, 2015. S. Harissopulos: "Studying nucleosynthesis at explosive environments in the lab".

- Invited Lecture given at the University of Peloponnese, Kalamata, January 12, 2016; S. Harissopulos: "Introduction to Ion-Beam Technologies and Associated Analytical Methodologies"

- Invited presentation at the NuPECC Strategy Meeting, Darmstadt, January 16, 2016; S. Harissopulos: "European Small-Scale Accelerator Facilities"; see in the list of presentations given in

  http://www.nupecc.org/index.php?display=presentations/talks

- Invited seminar given at the Dept. of Physics of the University of Crete, Heraklion, June 9, 2016; S. Harissopulos: "Capture reactions for the modelling of the p-process of explosive nucleosynthesis".

- Invited Lecture given at the Meeting "Fascination Physics" organized by the Union of Greek Physicists (Ενωση Ελλήνων Φυσικών) for Secondary School Students at the Technological-Educational Institute (TEI) of Athens. S. Harissopulos: "Nuclei in the Cosmos: Laboratory studies of Nucleosynthesis during Supernova explosions", December 16, 2016.

- Invited talk at the "Workshop p-process", held on February 20-22, 2017, Lyon, France; S. Harissopulos: "Experimental studies of the Demokritos group relevant to p-process, experimental setups, facility opportunities, recent results and near-future programs"
- Invited talk given at the Dept. of Physics of the Aristotle University of Thessaloniki, Greece, May 2, 2017; S. Harissopulos: "The CALIBRA Research Infrastructure of the National Roadmap for Research Infrastructures".
- Invited lecturer at "The Fourth Azarquiel School of Astronomy: a Bridge between East and West", June 11-16, 2017; Portopalo di Capo Passero - Syracuse, Italy; S. Harissopulos: "Experimental Nuclear Astrophysics - Direct Methods"; https://agenda.infn.it/contributionDisplay.py?sessionId=10&contribId=65&confId=12080

ORAL PRESENTATIONS IN WORKSHOPS

- 1st ENSAF Workshop, Sevilla, Spain, 19-21 Oct. 2016; S. Harissopulos: The Tandem Accelerator Laboratory of the National Centre for Scientific Research "Demokritos" and the CALIBRA project for its expansion and upgrade" https://indico.ific.uv.es/event/2824/contributions/
- The nu-ball hybrid spectrometer workshop 2016, May 19-20, 2016, Orsay, France; S. Harissopulos: "Capture reactions for explosive nucleosynthesis studies with the nu-ball"; https://indico.in2p3.fr/event/12783/timetable/#all
- WPJET2 meeting: Culham, United Kingdom, April 04 - 05, 2016; A. Lagoyannis: "Deuteron Nuclear Reaction Analysis and micro - beam facility at NCSR "Demokritos"
- p-process workshop 2015: status and outlook, Limassol, Cyprus, June 10 - 13, 2015; V. Foteinou: "Cross section measurements of proton capture reactions for the p process"; http://exp-astro.physik.uni-frankfurt.de/meetings/pProcessWorkshop2015/talks.php
- p-process workshop 2015: status and outlook, Limassol, Cyprus, June 10 - 13, 2015; G. Provatas: "Systematic cross section measurements of (α,γ) reactions for astrophysics" http://exp-astro.physik.uni-frankfurt.de/meetings/pProcessWorkshop2015/talks.php

MEMBERSHIP IN ADVISORY COMMITTEES OF INTERN. CONFERENCES, WORKSHOPS & SCHOOLS

- INPC 2016 – 5 Adelaide, Australia, September 11-16, 2016 (S. Harissopulos) http://www.physics.adelaide.edu.au/cssm/workshops/inpc2016/
- ND2016 – International Conf. on Nuclear Data for Science and Technology, Bruges, Belgium, September 11-16, 2016 (S. Harissopulos)
- 13th Russbach School on Nuclear Astrophysics, Russbach, Austria, March 6-12, 2016; (S. Harissopulos): http://indico.universe-cluster.de/indico/conferenceDisplay.py?confId=3470
- AccApp'15 – The 12th International Topical Meeting on Nuclear Applications of Accelerators, Washington DC, USA, November 10-13, 2015; (S. Harissopulos Organizer of Topic "Industrial Applications"): http://accapp15.org/
- EuNPC 2015: 3rd European Nuclear Physics Conference, Groningen, Netherlands, Aug. 31 – Sept. 4, 2015. (S. Harissopulos): http://www.eunpc2015.org/committees-2/international-advisory-committee/

- p-process workshop 2015: status and outlook, Limassol, Cyprus, June 10 - 13, 2015; (S. Harissopulos): http://meetings.nscl.msu.edu/pprocess2015/index.php?id=conference_details/main.php
- NN2015 – The 12th Intern. Conference on Nucleus – Nucleus Collisions, Catania, Italy, June 21 to 26, 2015; (S. Harissopulos): https://agenda.infn.it/internalPage.py?pageId=2&confId=5235
- 12th Russbach School on Nuclear Astrophysics, Russbach, Austria, March 8-14, 2015; (S. Harissopulos): http://indico.universe-cluster.de/indico/conferenceDisplay.py?confId=3237

The TANDEM Accelerator Laboratory – TAL

Sotirios V. Harissopulos (Director of Research)
Anastasios Lagoyannis (Principal Researcher)
Michail Axiotis (Research Associate)
Varvara Foteinou and Georgios Provatas (Postdoc Fellows)
Miltiadis Adrianis (Chief Engineer)
Vassilios Andreopoulos (Operator), Emmanouil Tsopanakis (Workshop Technician)
Kostas Preketes-Sigalas, Eleni Ntemou (PhD students)

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A Center of Excellence – A National Research Infrastructure

INPP hosts the only accelerator operating in the country, an electrostatic Van de Graaff Tandem accelerator with a maximum acceleration voltage of 5.5 MV. It is a low-energy ion-beam facility, one of the few accelerators of its kind in Europe. It started operating in the 1973 and ever since hosts a very successful multidisciplinary research program being the major scientific instrument not only of the INPP Nuclear Physics and Applications group but also of many other nuclear physics groups from the Greek Universities. Research groups from abroad are also performing measurements at the INPP Tandem, in collaboration with their Greek collaborators.

The accelerator has undergone severe upgrades in the period 2009-2012 thanks to an EC/FP7/REGPOT grant with the acronym LIBRA[8] (Contract No. 230123) of almost 1.5 million Euros. The successful implementation of LIBRA granted the status of a "Center of excellence in Low-energy Ion-Beam Research and Applications" to the TAL and placed it among leading European low-energy ion-beam laboratories. TAL is currently coordinating the "European Network of Small-scale Accelerator Facilities" (ENSAF)[9], a network of the "European Nuclear Structure and Applications Research" (ENSAR)[10] Integrating Activity funded by the "Horizon 2020" framework program of the European Commission (EC). To date, the TANDEM Accelerator Laboratory is recognized by the international scientific community as a laboratory of international stature.

Thanks to LIBRA funds, new state-of-the art instruments and accelerator components have been acquired, including a focused micro-beam system, new HV supplies for quadrupoles and beam-steerers, brand new data-acquisition units and radiation detectors. The major achievement of LIBRA, however, is the creation of a User's Group around the

[8] http://libra.inp.demokritos.gr/
[9] http://www.ensarfp7.eu/activities/networking-activities/ensaf/what-is-ensaf
[10] http://www.ensarfp7.eu/

upgraded accelerator laboratory and the new facilities developed during the course of the project. By the end of the LIBRA project, the LIBRA Users Group consisted of almost 50 external users from Greece and Europe. As of today, at least 1000 hours of beam-time are offered to external users every year.

Motivated by the unique multidisciplinary features of the research activities carried out at the TAL, the establishment of a vibrant user's community, the continuously increasing demand for extra beam-time by external users and the generous donations by strategic partners of TAL, a 24 million project aiming at establishing a "Cluster of Accelerator Laboratories for Ion-Beam Research and Applications" with the acronym CALIBRA was submitted to the Greek funding agency GSRT within the call for establishment of the National Roadmap for Research Infrastructures. The aforementioned donations include a 250-keV high-current proton-deuteron accelerator (by the French IN2P3), a 18 MeV Scanditronix PET cyclotron (by UMCG [11], the Dutch University Medical Center Groningen) and the GASP-BGO Ball, comprising of 80 BGO scintillator detectors (from the Italian INFN). The National Roadmap for Research Infrastructures was formally announced in December 2014. CALIBRA was included therein, as one of the excellent proposals (score 19/20) evaluated by an international expert committee setup by GSRT.

In its original version, CALIBRA proposed the establishment of a Research Infrastructure including a cluster of 5 accelerators: a Tandem accelerator, the 250-keV PAPAP high-current accelerator, the aforementioned 17-MeV Scanditronix cyclotron, a new single-stage electrostatic accelerator with an ECR ion source for very high currents of ion beams, from protons up to gold, and a new AMS 1 MV accelerator. These accelerators were proposed to form three interconnecting laboratories equipped with common experimental devices and state-of-the-art instrumentation. Between the formal announcement of the National Roadmap for Research Infrastructures (RI) in December 2014 and July 2016, no funding was provided by GSRT to any RI of the National Roadmap. Instead, CALIBRA has gone through repeated evaluations, also in terms of the so-called RIS3 Greek national priorities [12], and was finally included for funding within the national "Partnership Agreement for the Development Framework 2014-2020" (ΕΣΠΑ 2014-2020), which is

[11] https://www.umcg.nl/EN/corporate/The_University_Medical_Center/Paginas/default.aspx
[12] http://s3platform.jrc.ec.europa.eu/regions/EL

the strategic plan for growth in Greece with contribution of resources originating from the European Structural and Investment Funds (ESIF) of the European Union. The formal ministerial decision to fund CALIBRA with a budget of 3.42 million Euros has been communicated in October 30, 2017. As a result of these delays, the kick-off meeting of CALIBRA was held in November 6, 2017. The meeting was attended by more than 60 scientists from 17 Greek research performing institutions and state organizations.

New instruments and hardware upgrades between 2015 and 2017

During the reporting period 2015-2017, new instruments were installed and hardware upgrades were implemented. Most of the upgrades listed below have been motivated by the scientific needs of external collaborating groups and were accomplished jointly with the scientific and technical personnel of the TANDEM Accelerator Laboratory.

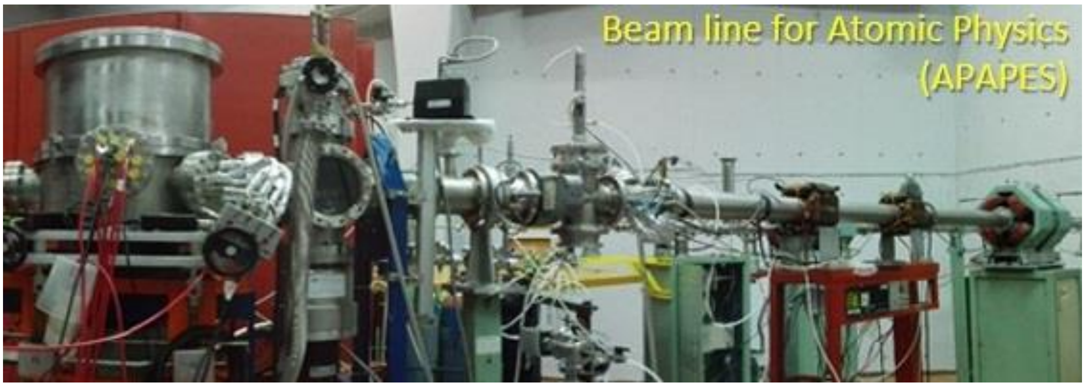
I) UPGRADES WITHIN THE APAPES COLLABORATION FOR ATOMIC PHYSICS

APAPES[13] is the acronym of the project entitled "Atomic Physics with Accelerators: Projectile Electron Spectroscopy at the NCSR Demokritos Tandem accelerator". It is the first research project in Greece using accelerators for atomic physics investigations with the goal to perform measurements of the excitation of the projectile ion using high resolution Auger electron spectrometry. APAPES is coordinated by Prof. Theo Zouros from the Department of Physics of the University of Crete. During 2015-2017 following upgrades were completed or launched and are under progress:

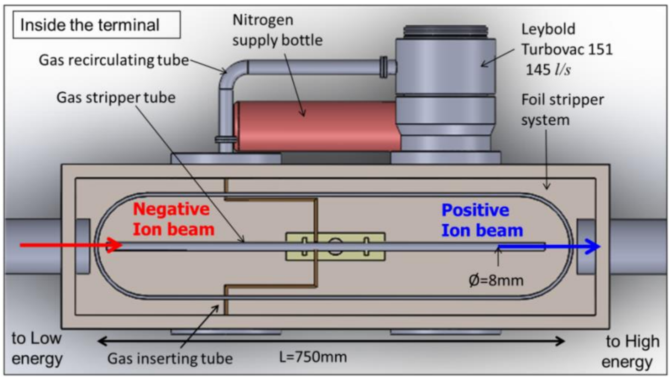
Atomic Physics Beam-Line: APAPES has established a new experimental station with a beam line dedicated for the investigation of atomic collisions. Apart from the main ion-beam focusing elements and vacuum stations, a state-of-the art zero-degree Auger projectile spectrometer (ZAPS) has been installed at the L45 beam-leg allowing for high resolution studies of electrons emitted in ion-atom collisions. The goal of the project is to provide a more thorough understanding of cascade feeding of the 1s2s2p ^4P metastable states produced by electron capture in collisions of He-like ions with gas targets and further elucidate their role in the non-statistical production of excited three-electron 1s2s2p states by electron capture, recently a field of conflicting interpretations awaiting further resolution. The Tandem Lab hosts the experimental setups of APAPES and provides the

[13] http://apapes.physics.uoc.gr/

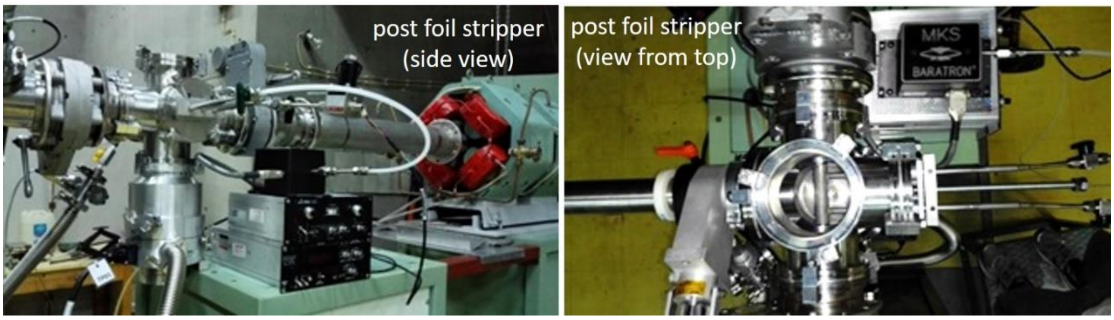
ion beams for the relevant experiments as well as work space for the scientists and the post-graduate students engaged in the project.



Installation of a gas stripper at the high-voltage terminal of the Tandem: When a negative ion passes through a medium, it may lose one or more of its electrons through collisions and become positive. The probability of ionization depends, among other parameters, on the thickness of the stripping medium. This process is known as the stripping process and is the standard technique used in the terminal of a Tandem Van de Graaff accelerator. The stripping medium may be solid (thin foils) or gas. The terminal stripper of our Tandem Accelerator is equipped with a chain holding 80 carbon foils as the stripping medium. The disadvantage in the use of foils is that, as their thickness is predefined, the probabilities of the final charge states cannot be adjusted. To improve the stripping performance of the accelerator, a gas stripper using nitrogen was installed at its high-voltage terminal. The pressure of the gas can be regulated through a remotely controlled valve. This way the effective thickness of the stopping medium is changed and a better adjustment of the distribution of the final charge. A drawing of the gas terminal stripper installed is shown on the right.

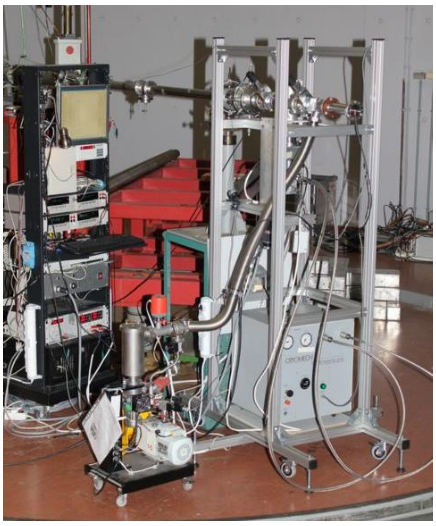


Installation of the post – stripper: The post-stripper system, consisting of a gas and a foil stripper, was installed at the beam line between the analyzing and switching magnets of the Tandem. This addition was essential for the production of highly charged ions in general and, in particular, for the helium like ions used for projectile electron spectroscopy. Pictures of the installed post foil stripper is shown below.



II) UPGRADES IN COLLABORATION WITH THE FUSION TECHNOLOGY GROUP

The Fusion Technology Group (FTG)[14] is a team of researchers of the Inst. of Nuclear and Radiological Sciences & Technology, Energy and Safety (INRaSTES) of "Demokritos". It collaborates for almost 10 years with the group of the Tandem Accelerator Laboratory in the study of materials relevant to energy production via fusion. Apart from standard ion-beam analytical techniques, such as Rutherford Backscattering (RBS) and Nuclear Reaction Analysis (NRA), FTG performs ion irradiations of materials with in-situ electrical resistivity measurements. For this purpose, a dedicated setup, the IR^2 that stands for Ion iRradiation with in-situ electrical Resistivity measurement has been developed by the FTG group and installed jointly with the TAL group at the L60 beam-leg of the accelerator as shown by the picture on the right. The IR^2 irradiation facility is described in http://ipta.demokritos.gr/ftg/ir2.html.



III) INSTALLATION OF A NaI(Tl) CALORIMETER FOR NUCLEAR ASTROPHYSICS

Low-energy accelerators, like the INPP Tandem, have been used for many decades to search for our cosmic origins. The answer to this quest has been a driving force in mankind's cultural evolution through-out the centuries giving birth, among other disciplines, to Nuclear Astrophysics, a vastly interdisciplinary field that deals with a large number of different problems requiring input from a variety of different scientific domains such as nuclear physics, astronomy, astrophysics, nuclear chemistry, geophysics, meteoritics, planetology, and, since recently, astrobiology.

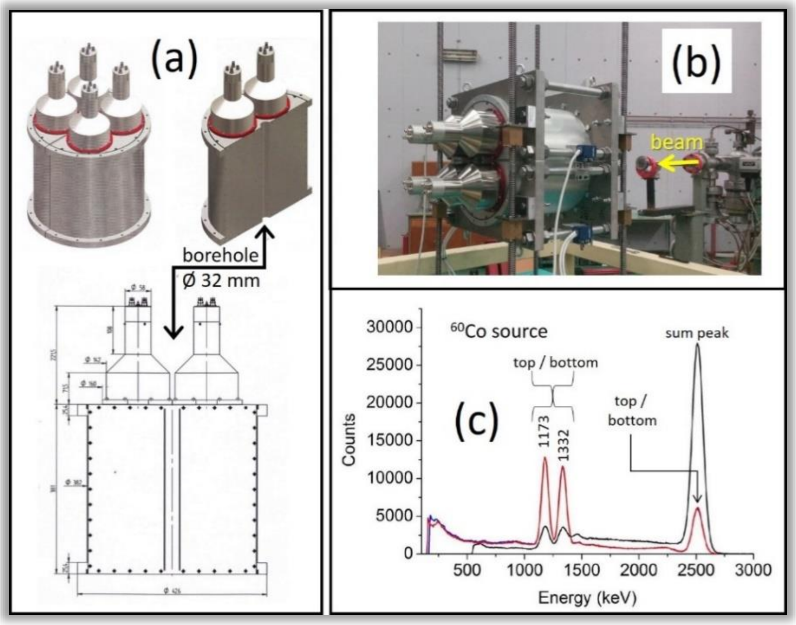
In this context, a research program related to stellar nucleosynthesis was launched in the early nineties at the Tandem accelerator of "Demokritos" and a vibrant nuclear astrophysics (NA) group has gradually been formed. Since then the NA group has carried out numerous measurements at the in-house Tandem as well as abroad, in collaboration with various well-established nuclear astrophysics groups, and to date, plays a worldwide leading role in stellar nucleosynthesis studies focusing, primarily, on nuclear reactions related to the understanding of the *p process*, i.e. the nucleosynthetic mechanism of certain

[14] http://ipta.demokritos.gr/ftg/index.html

neutron-deficient nuclei heavier than iron in explosive stellar environments, such as supernovae.

The major experimental challenge in p-process studies is to perform absolute cross-section measurements of proton- and α-particle induced capture reactions on nuclides heavier than iron at energies far below the Coulomb barrier, i.e. to investigate capture reactions with cross sections often below one micro-barn. To accomplish this task successfully and within reasonable beam time, the Experimental Nuclear Physics and Applications group of INPP has developed a new technique, the 4π γ-summing method[15]. This method takes advantage of the ability of a large volume NaI(Tl) crystal to sum photons up to 15 MeV, or even more with high efficiency. The group has conducted systematic measurements at the Dynamitron Tandem Laboratorium (DTL) of the University of Bochum, Germany, using the local 12"x12" NaI(Tl) single crystal.

In the meantime, thanks to LIBRA funds a new 14"x14" summing NaI(Tl) two-fold segmented summing detector, coined NEOPTOLEMOS, was purchased and installed at the R60 beam-leg of the Tandem accelerator. The detector is shown in the following figure comprising parts (a), (b) and (c). Part (a) displays its two halves with a borehole in between. Its arrangement at the beam line of the accelerator is shown in part (b). A spectrum of a ^{60}Co source taken with the spectrometer is plotted in part (c). The strong 1173 and 1332-keV lines are those detected without summing the signals from the two halves ("top" and "bottom"). Summing the signals results in the sum peak located at 2500 keV. The absolute efficiency for the sum peak is ≈50%. The energy resolution of the detector is ≈5% for the 1332-keV γ-line and ≈4% for the sum peak.



IV) BEAMLINE UPGRADES

Upgrade of the R32.5 beamline: One of the major and standard focusing elements used in accelerators is the quadrupole. The beam lines at the Tandem accelerator are equipped with double element focusing quadrupoles i.e. two coupled quadrupoles focusing in the X and Y direction. In the upgrade-process of the R32.5 beamline (hosting an RBS chamber), the old doublet quadrupole was replaced with a new one consisting of three quadrupole

[15] See, e.g., "Cross-section measurements of capture reactions relevant to p-process nucleosynthesis" by S. V. Harissopulos in Eur. Phys. J. Plus (2018) 133:332; https://doi.org/10.1140/epjp/i2018-12185-8

elements (triplet) to improve the focusing of the beam. The mechanical installation has already finished while the water cooling and electrical connections are ongoing.

Installation of the new R15 beamline: The significant increase of new experimental setups in the last few years resulted in the lack of available beam lines to host dedicated experimental devices. To overcome this problem and expand further the capabilities of the Accelerator Laboratory, installation works of a new beamline (R15) in the green target room have started. So far, the beam line was extended from the switching magnet to the green room and an electrical triple quadrupole was installed along with the pumping system. The installation will continue by further extending the beamline and adding additional pumping units, collimators and control systems. The beamline will host the newly acquired 4π γ-summing detector NEOPTOLEMOS and a new turntable, where five Hyper-Pure Ge detectors (HPGe) equipped with BGO Anti-Compton Shields will be installed for the measurement of γ-angular distributions.

Beamline Upgrades

Top:
Quadrupole replaced at the R32.5^{O} beamline (left picture) with the triplet shown in the right picture.

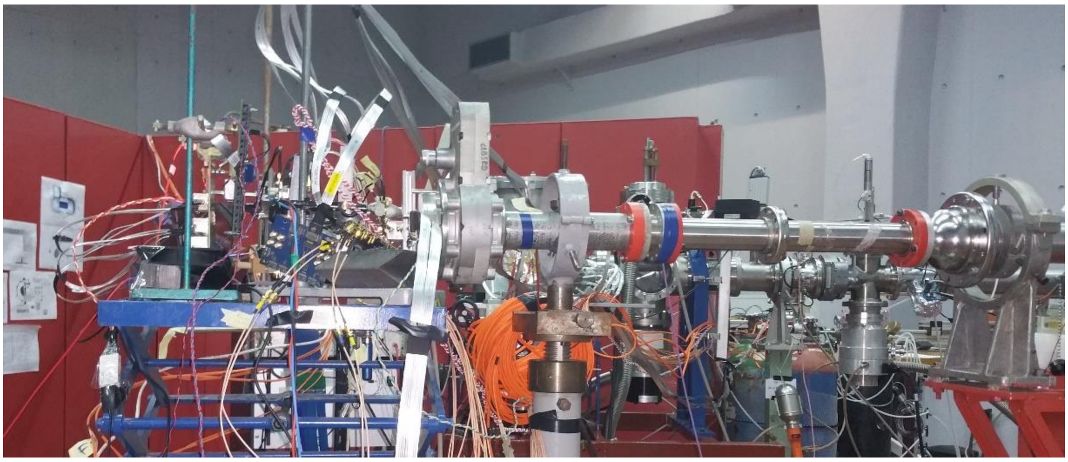
Right:
electrical triple quadrupole installed at the new R15^{O} beamline

An Open-Access Research and Training Infrastructure for the national and the European scientific community

The TANDEM Accelerator Laboratory offers every year, on the average, around 1000 hours of beam-time to external users. As such is an open-access research infrastructure for the benefit of the national and European scientific community. Its facilities are used for a wide spectrum of activities in basic research and applications. Some examples of experiments performed by external users are presented in the following.

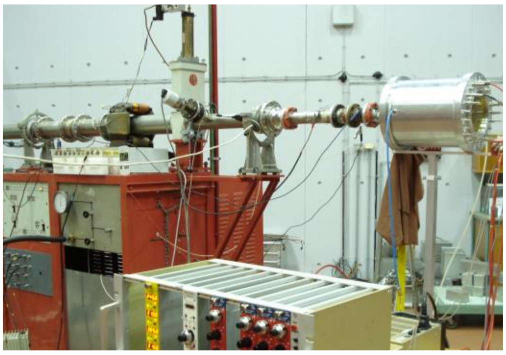
The LHC-ATLAS irradiation week: In the Phase-1 upgrade of the ATLAS detector expected for 2018/19 at CERN, MicroMegas detectors will be introduced in the area of the small wheel at the end caps. For this purpose, accompanying new electronics, such as the VMM front end ASIC, have been designed and built to provide energy, timing and triggering information and to allow for fast data read-out. The first version of VMM (VMM1) has already been produced. Before its integration in the ATLAS upgrades, the response of the VMM1 configuration registers requires testing under harsh radiation environments.

Motivated by these test needs, members of the Greek LHC/ATLAS Group from the National Technical University of Athens – NTUA (12 scientists), the University of Athens (2), the Aegean University (2), the University of Western Attica (2) and INPP (1), together with collaborators from Italy (2), Romania (1), USA (5) and Israel (1) performed neutron irradiations at the Tandem accelerator. Photos from the irradiation setup and members of the group during the measurements are displayed below.



Fission studies using a MicroMEGAS detector: The Micromegas detectors are gaseous detectors, very robust, cheap and easy to construct. They also utilize the micro-bulk technology. Kapton and copper are high radio-purity materials, making them ideal construction materials of such a detector. With these features, MicroMegas detectors are in the leading edge of nuclear and particle physics research. Moreover, MicroMegas detectors are ideal tools for neutron experiments due to their low mass that contributes to the reduction of neutron scattering. Using a MicroMegas detector developed for fission studies, the NTUA Nuclear Physics Group performed at the INPP Tandem cross section measurements of the ^{237}Np(n,f) reaction at neutron energies from 4.5 to 5.3 MeV. Neutrons were produced via the ^{2}H(d,n)^{3}He reaction. The experimental setup with the MicroMegas mounted at the L60 beamline is shown in the next left picture below.

Testing the response of Diamond detectors in neutron-induced particle-emission: In May 2016, a group from TUW, the Technical University of Vienna, coordinated by Dr. Christina Weiss and Prof. Erich Griesmayer, in collaboration with the NTUA Nuclear Physics Group, have tested the response of diamond detectors, produced via synthetic chemical vapour deposition (CVD), in cross section measurements of (n,α) reactions relevant to nuclear astrophysics studies. The reaction used for this purpose was ^{12}C(n,a). The right picture below is a photo of the researchers, who participated in the irradiations.



Training of Physics students from TU Wien, Austria: A group of 10 physics Students (4th and 5th year) of the TU Wien (University of Technology of Vienna) led by Prof. Leeb visited the Institute of Nuclear and Particle Physics at NSCR Demokritos in the period June 6-9, 2017. Under the guidance of Dr. Lagoyannis an introduction into the techniques of nuclear physics experiments with hands on activities on experimental setup, measurements and subsequent analysis was performed at the Tandem Accelerator of the institute. The great and highly didactic engagement of the institute members was highly appreciated by the Viennese students who received a very clear view on the art of experimental techniques in the nuclear field, important not only for basic research but also for numerous applications. (*Press Release, Prof. Helmut Leeb, June 9, 2017*)

Cadet Researchers Week («Δόκιμοι Ερευνητές»): The Tandem Accelerator Lab is strongly engaged in the annual event, coined "Cadet Researchers" («Δόκιμοι Ερευνητές») since 2015, when it was first launched. The event is designed for high school students in the 2^{nd} class, who spend a week at the INPP and perform basic introductory experiments under the guidance of INPP scientists.

<u>Outreach Activities</u>

The Tandem Accelerator Laboratory offered every year 35 to 40 guided tours to students from high-schools. As a result, from 2015 to 2017 more than 3000 pupils have visited the accelerator facilities. Moreover, the TAL has actively participated in the Pan-European event "Researcher's Night" that was organized in September every year. From 2015 to 2017 more than 2000 visitors of all ages had the opportunity to visit the lab and get informed about the running research activities. Finally, a few special events for the public have been organized. The following two pictures are typical examples of the attendance of high-school students (left) in a "Researcher's Night" event and in a guided tour of the public at the tandem accelerator after a dedicated event on nuclear astrophysics jointly organized with the "Café Scientifique" of Athens, in May 2016.

May 12, 2016

Guided tour for the public
more than 100 visitors

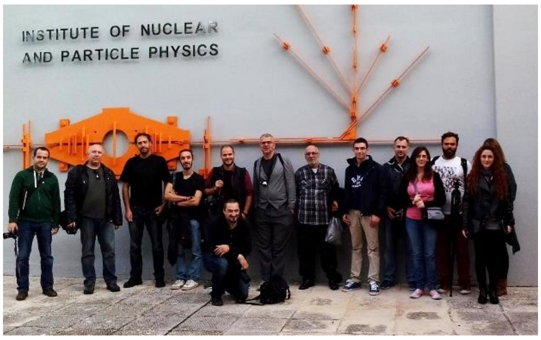
September 2015

"Researcher's Night"
more than 800 visitors

June 15, 2016.

Guided tour to 16 accelerator experts from Canada, Egypt, Germany, India, Italy, Indonesia, Jordan, Korea, Malaysia, Russia, UK, USA and the IAEA in the framework of an IAEA Technical Meeting held at Demokritos.

November 26, 2015: Greek professional photographers taking pictures of the Tandem accelerator in order to participate with their photo creations in the European Science Photo Competition 2015 of Wikimedia.



Some VIP Visitors of the Tandem Laboratory from abroad:

- April 2016: The Alternate Minister of Education and Science of the Russian Federation, Ms Ludmila Ogorodova, accompanied by Russian Delegation.
- June 2, 2016: The General Director of the National Office for Science and Technology Awards of China (NOSTA), Mr. Dating Zou and Chinese Delegation
- October 25, 2016 The General Secretary of the Ministry of Science and Technology of F.R. China, Mr. Xu Jianpei, and Delegation.

Multimedia for Tandem: "The Tandem Accelerator Lab at INPP NCSR Demokritos" (Youtube; video in Greek): https://www.youtube.com/watch?v=HqI9TVDVMsU

Strategic Partnerships and Collaborations

- French National French Laboratory for Heavy-Ion Research GANIL, Caen (MoU signed)
- INFN Laboratori Nazionali di Legnaro – LNL, Italy (MoU signed)
- IN2P3 Centre de Spectrométrie Nucléaire et de Spectrométrie de Masse (CSNSM), Orsay, France
- Vinča Institute of Nuclear Sciences, Belgrade, Serbia (MoU signed)
- RUBION–Dynamitron Tandem Labor (DTL), Ruhr-University Bochum, Germany
- Institut für Kernphysik, Universität zu Köln, Germany
- More than 10 European accelerator laboratories engage in the implementation of the CALIBRA Research Infrastructure.

Forward Look

In March 2018, the Tandem Accelerator Laboratory has become 45-years old. It was in March 1973 when "the beam on target" was announced for the first time. Since then, the laboratory has gone through different phases, in terms of scientific programs, funding and staffing. During all these years, the lack of state support in providing budget for operation, maintenance and necessary upgrades as well as in hiring scientific and technical personnel, was clearly documented in all external and internal evaluation reports. The FP7/REGPOT LIBRA project with a budget of almost 1.5 million Euros has, partly, improved the situation in maintenance and basic upgrades. In this direction, the recently launched CALIBRA project is expected to give a drastic boost in the TAL's capabilities, state-of-the art facilities and instrumentation. In addition, more than 10 young scientists are expected to be hired for CALIBRA's implementation, however with time-limited contracts. Under these conditions, following priorities are set and need to be achieved in the next 3-5 years.

1) Improve staffing: A permanent position for the post of the chief engineer is urgently required. In addition, a young "operational scientist" («Ε.Λ.Ε») with PhD is necessary to assist not only the in-house researchers in their scientific program but also to act as a lab-bridge for external users within the framework of TAL's character as a future national research infrastructure. These positions, and two more ones, have been fully justified and recommended by the expert committee, who has performed the last external evaluation of the lab (February 2014) on behalf of GSRT.

2) Accomplish the CALIBRA project: The successful implementation of CALIBRA is of vital importance for TAL. It will secure a frictionless operation for at least 10 years to come, equip the lab with state-of-the art facilities and instruments allowing for forefront low-energy nuclear research and ion-beam based innovative applications, in compliance with the national thematic priorities set by the "Smart Specialization Policy" (RIS3). CALIBRA will enhance further the role of TAL as a prominent European laboratory.

3) Enhance the lab's open-access character: It is among the lab's priorities to provide more beam-time to external users for fundamental research and ion-beam applications. To keep the level of excellence in its program, an International Scientific Advisory Committee (ISAC) lead by Prof. Muhsin N. Harakeh (KVI-CART, Univ. of Groningen, the Netherlands) has been established. ISAC will advise on the scientific

merit of the experiments to be carried out at the TAL as well as within the CALIBRA project, starting from January 2019. It is worth noting that the establishment of an independent TAL User Group is foreseen to be funded by CALIBRA. Moreover, TAL is currently engaged in joint efforts of the European Nuclear Structure and Applications Research (ENSAR) community to submit a proposal to EC, within the next Horizon-Europe framework program. In this proposal, that aims at funding the follow-up Integrating Activity, TAL is proposed as one of the Trans-National Access facilities, being thus fully integrated within the European Nuclear Physics Community.

4) Education, Training and Outreach: TAL aims at a severe upgrade of its role as a unique educational and training site for graduate and post-graduate students of Greek as well as European Universities. In this context, intense efforts will be made to offer attractive topics to students and supervise them co-equally together with University colleagues. Specially designed training activities are also prepared. Outreach activities will be enriched with special events, the production of multimedia and informative material for the general public, the organization of "open-days" and the offer of well-prepared guided tours.

XRF Laboratory

Research activities of the XRF Laboratory (2015-2017)

1) Revisiting X-ray fundamental parameters using synchrotron radiation-based benchmarking experiments.

This activity follows systematic experimental work carried out at the the INPP Tandem accelerator using high intensity and energetic (~1.5-2 MeV) proton beam to generate quasi monochromatic X-ray beams (PIXE-induced XRF technique). For the implementation of the combined PIXE-XRF analytical methodology a dedicated setup has been developed at the INPP (D. Sokaras, et al., Review Scientific Instruments 83 (2012) 123102; doi: 10.1063/1.4768735) and basic phenomena such as the Resonant Raman X-ray Scattering and the L- cascade X-ray emission were studied. The Demokritos results were compared with synchrotron measurements performed at BESSY II and excellent agreement was observed (D. Sokaras, et al., Physical Review A83 (2011) 052511(12); Physical Review A81 (2010) 012703(9)).

During the period 2012-2015 the scientific responsible of the XRF laboratory coordinated on behalf of the International Atomic Energy Agency (IAEA) the development at Elettra Sincrotrone Trieste of a novel synchrotron radiation beam-line end-station (IAEAXspe). This instrument intended to be used for X-ray spectrometry based interdisciplinary applications and fundamental research (see A.G. Karydas et al., Journal of Synchrotron Radiation 25 (2018) 189–203, Wrobel et. al. NIMA 833 (2016) 105–109). Under this framework, international collaborations were established, whereas through successful beamtime proposals and the execution of specifically designed benchmark experiments the aforementioned basic research activity has been further continued and enhanced. Since 2015 experimental studies have been carried out to evaluate systematically different X-ray fundamental parameters and X-ray Fluorescence production and Resonant Raman Scattering cross sections for Dy **[1, 2]** and Ge atoms (work in progress). In particular for Dy, a broad range of fundamental X-ray parameters was experimentally determined including attenuation coefficients, photo-ionization cross sections, Lj (j=1-3) sub-shell fluorescence and Coster-Kronig yields, whereas the Dy Lj (j=1-3) and Mk (k = ξ, αβ, γ, m) XRF production cross sections were also reported [**1-2**]. Interestingly, by probing the Mk x ray emission, the evolution of the probability for the cascade Lj sub-shell vacancy decay as the tunable energy incident photons progressively ionize different Lj sub-shells of Dy was investigated for the first time.

Outlook

The research related to the evaluation of the accuracy of existing databases of X-ray fundamental parameters, secondary processes and formulation schemes that predict the enhancement of the X-ray fluorescence intensities beyond the primary photoionization process, contributes to the improvement of the traceability of uncertainties in quantitative standard less XRF analysis. The results obtained so far are very promising and have revealed not only significant discrepancies between theoretical and experimentally determined X-ray fundamental parameters but have also provided insight to atom relaxation and fluorescence emission processes that have not been studied so far. In the forthcoming years (2018-2019) the systematic experimental work will continue utilizing synchrotron radiation as an exciting source focusing on the determination of Ge (Z=32) and Re (Z=75) fundamental X-ray parameters, the study of the Re-M and Ge-L cascade X-ray emission and the determination of Resonant Raman scattering cross sections.

2) Research and development of X-ray spectrometry interdisciplinary applications

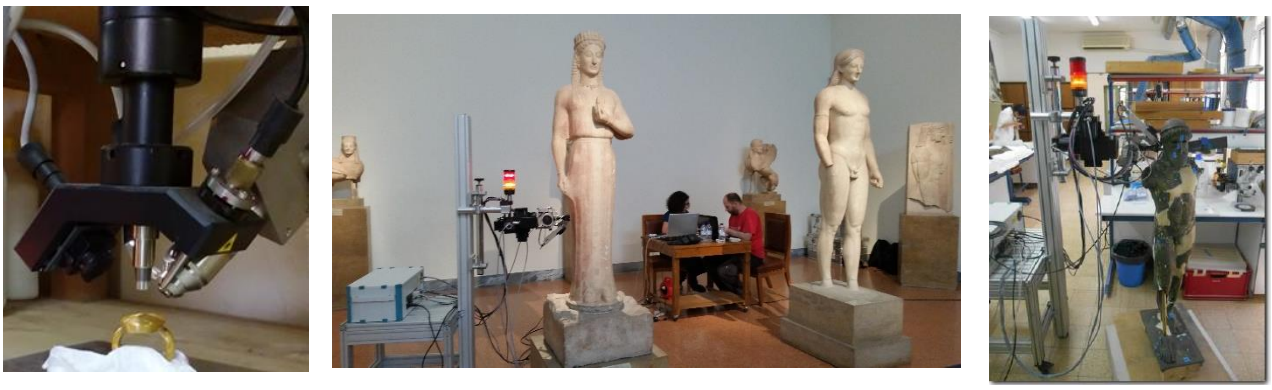
Since 2015 the XRF laboratory has established a strong and fruitful collaboration with the Environmental Radioactivity Laboratory (ERL) of the Institute of the Nuclear and Radiological Science & Technology, Energy & Safety at NCSR "Demokritos". Through this collaboration a powerful XRF spectrometer (E5 model by Panalytical) acquired by the ERL with the support of a European project (ENTEC, FP7-REGPOT, 2013-2016) has been installed and continuously operates at the XRF premises. The XRF spectrometer is mainly used for the analytical characterization of aerosol samples (PM2.5 and PM10) in support of atmospheric research projects **[6,21]**, industrial applications and regulatory compliance with PM10 limit values, but it is also exploited to further develop its applicability towards trace element analysis of different kind of samples. For example, in a recent published work **[12]** the E5 XRF spectrometer was utilized to evaluate the efficacy of Pt based anticancer drug delivery systems based on different animal organs by assessing their enhanced cytotoxic properties to tumorous tissues and the reduced toxicity to other organs. Generally, the activities of the XRF laboratory have provided key contributions in the following thematic areas (with bold numbers the publications which have been exclusively supported by the XRF laboratory infrastructure are indicated):

1. X-ray spectrometry analytical methodologies [5, 8, **18**]
2. Environment [**6**, 11, 14-15, **21**]
3. Biomedicine/Pharmaceutical [4, **7**, **12**]
4. Advanced materials characterization [20]
5. X-ray spectrometry instrumentation [13, 17]
6. Geochemistry [**9**]
7. Cultural Heritage [**3, 10,** 16**, 19**]

In the field of Cultural Heritage, highlighted XRF applications and collaborations were conducted with important partners such as the Institute of Historical Research of the National Hellenic Research Foundation, the National Archaeological Museum, the Cycladic Museum and the Department of Classics of the University of Cincinnati, by analyzing unique archaeological material such as the recently excavated objects from the Griffin Warrior grave (gold rings, glass beads), the bronze statue of the Poseidon of Livadostra, the polychromy on the Phrasikleia statue [**10**], wall-painting fragments from the Nestor Palace in Pylos Messinia, gold jewels from the Mycenean cemetery of Deiras, Argolida, the Archaic Pitsa panels (the oldest painted wooden artifacts from antiquity) and the remaining polychromy on the famous Cycladic figurines from the National Archaeological Museum and the Cycladic Museum. Through a multi-scale collaboration established with the LANDIS laboratory of INFN and CNR, macroscopic XRF imaging (MA-XRF) was applied in-situ at several Greek museums (National Archaeological Museum, Cycladic museum, Archaeological museum of Kerameikos and at the archaeological museum of Chora Messinias), whereas methodological improvements were investigated, in particular towards the development of the MA-XRF quantitative imaging.

Outlook

Different modalities of the XRF analysis technique are nowadays widely established in many disciplines as a mandatory analytical tool to offer advanced and non-destructive characterization of materials with 2D and 3D spatially resolved elemental information, in-situ, at small laboratories or at large infrastructures (synchrotrons). The continuously improved technical features of new generation X-ray detectors and of the energy-dispersive pixelated cameras, fast digital signal processors, and X-ray focusing devices, but also the availability of brilliant and miniaturized X-ray sources and fast spectrum analysis packages boost the XRF technology to new eras of analytical applications. There is a constant demand to the XRF laboratory of the INPP for supporting archaeological, conservation, environmental and biomedical research projects, but also educational activities such as MSc and Diploma dissertations. However, there is a critical requirement that it should be equipped with an upgraded X-ray instrumentation, for example Silicon Drift Detectors of large area, X-ray optical devices, modern digital signal processing units and fast motorized stages. The unintended access at Elettra Sincrotrone Trieste will further support the continuation of the basic research program in X-ray spectrometry, and particular effort will be given to strengthen interdisciplinary collaborations for synchrotron radiation applications.



(a) (b) (c)

In-situ micro-XRF measurements performed: a) At the Archaeological museum of Chora Messinias by analyzing a gold Mycenean signet ring recently excavated (2015) from the Griffin Warrior grave by a team of the University of Cincinnati, b) at the National Archaeological Museum by analyzing the polychromy on the statue of Phrasikleia and c) at the same museum by evaluating the chemical composition and state of preservation of the bronze statue of the Poseidon of Livadostra.

Outlook

The broad range of the XRF laboratory activities and published record clearly indicates the significant role that this particular technique plays in modern analytical studies with interest in various disciplines. The progress in X-ray instrumentation developments (including sources, silicon drift and pixelated detectors with energy dispersive detection capabilities, digital signal processors, optics, miniaturization etc.) boosts dramatically the performance limits of the XRF methodologies. The XRF laboratory utilizing the existed instrumentation resources will continue to support non-destructive (in-situ, if necessary) characterization of archaeological materials/artifacts and artworks in support of archeological/conservation projects with particular emphasis to propose new analytical procedures and protocols.

XRF Laboratory Group members

- Vasiliki Kantarelou, Post Doc researcher
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Collaborators from Greek Academic and Research Institutions

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- Georgianna Moraitou, National Archaeological Museum
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- Sanjiv Puri, Department of Basic and Applied Sciences, Punjabi University, Patiala, Punjab, India
- Eva Margui, Department of Chemistry, Faculty of Sciences, University of Girona, Spain
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- Francesco Paolo Romano and Claudia Caliri, CNR, Istituto per i Beni Archeologici e Monumentali (IBAM) and Laboratori Nazionali del Sud, INFN, Italy

- Jorge Sanchez & Juan Jose Leani, National Scientific and Technical Research Council (CONICET), Argentina
- Alessandro Migliori, Nuclear Science and Instrumentation Laboratory, International Atomic Energy Agency, (IAEA) Laboratories, Austria
- Janos Osan, Environmental Physics Department, Hungarian Academy of Sciences Centre for Energy Research, Hungary
- Abdallah Shaltout, Spectroscopy Department, Physics Division, National Research Centre, Cairo, Egypt

Articles in Peer-Review Journals

2017

1. R. Kaur, A. Kumar, M. Czyzycki, A. Migliori, A. G. Karydas and S. Puri, "*Measurements of Fluorescence and Coster-Kronig yields for 66Dy using synchrotron radiation induced selective photoionization method*", NIM B 407 (2017) 210–216

2. R. Kaur, A. Kumar, J. Osan, M. Czyzycki, A. G. Karydas and S. Puri, "*Measurements of mass attenuation coefficients and determination of photoionization cross sections at energies across the Li (i=1-3) edges of 66Dy*", Radiation Physics and Chemistry 136 (2017) 30–37

3. J. Baker, V. Kantarelou, A. G. Karydas, R.E. Jones, P. Siozos, D. Anglos and B. Derham, "*The Height of Denier Toournois Minting in Greece (1289-1313) according to new archaeometrical data*", The Annual of the British School at Athens, (2017), pp. 1-41, DOI: 10.1017/S0068245416000113

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Articles in Book editions

H. Brecoulaki, S. Sotiropoulou, V. Kantarelou and I. Melianos, "*Colours and Pigments in the Miniatures of the Illuminated 'Book of Job' at the Monastery of St John the Theologian, Patmos* ", Manuscripts in the making Art & Science, Volume 1, Edited by Stella Panayotova & Paola Ricciardi, Harvey Miller Publishers, ISDN: 978-1-909400-10-8, pp. 156-169, (2017)

Ph.D. theses

Vasilike Kantarelou, "Development, evaluation and application of micro-X ray fluorescence spectrometry on cultural heritage", Department of Applied Mathematics and Physics, National Technical University of Athens **(2015)**

MSc Diploma Dissertations

"A micro-XRF investigation of the bronze statue of Poseidon of Livadostra", Athanasia Fragkou, MSc program *«Cultural Heritage Materials and Technologies»* of the Department of History, Archaeology and Cultural Resources Management, University of the Peloponnese **(2016)**

Support in MSc Diploma Dissertations

"*Analysis of vessel glass fragments from the Byzantine church of Transfiguration of the Saviour in Metamorfosis, Messinia, Peloponnese*", Maria Staikou, MSc program *«Cultural Heritage Materials and Technologies»* of the Department of History, Archaeology and Cultural Resources Management, University of the Peloponnese **(2016)**

"*Characterization of black crust on Pentelic and Karystos marble identification of pollution sources*", Dimitrios Mitsos, MSc program *«Cultural Heritage Materials and Technologies»* of the Department of History, Archaeology and Cultural Resources Management, University of the Peloponnese **(2017)**

Nuclear Structure Theory

Nuclear Structure Theory 2015-2017

1.1 Group members

Head of the group: Dennis Bonatsos, Director of Research

Ph.D. graduate students: Andriana Martinou (NTUA), Ioannis Assimakis (NTUA), Smaragda Sarantopoulou (NTUA)

Diploma thesis students: Spyridon Peroulis (NKUA)

1.2 International collaborators

Richard F. Casten, Yale U., USA

Klaus Blaum, Max Planck Institute for Nuclear Physics, Heidelberg, Germany

Nikolay Minkov, INRNE, Bulgarian Academy of Sciences, Sofia, Bulgaria

R. Burch Cakirli, Istanbul U., Turkey

1.3 Research project: Proxy-SU(3) symmetry

The SU(3) symmetry realized by J. P. Elliott in the sd nuclear shell is destroyed in heavier shells by the strong spin-orbit interaction. On the other hand, the SU(3) symmetry has been used for the description of heavy nuclei in terms of bosons in the framework of the Interacting Boson Approximation, as well as in terms of fermions using the pseudo-SU(3) approximation. We have introduced a new fermionic approximation, called the proxy-SU(3) [R5,R6,R7].

The proxy-SU(3) symmetry appears in heavy deformed even-even nuclei, by omitting the intruder Nilsson orbital of highest total angular momentum and replacing the rest of the intruder orbitals by the orbitals which have escaped to the next lower major shell [R5]. The approximation is based on the fact that there is an one-to-one correspondence between the orbitals of the two sets, based on pairs of orbitals having identical quantum numbers of orbital angular momentum, spin, and total angular momentum. The accuracy of the approximation has been tested through calculations in the framework of the Nilsson model in the asymptotic limit of large deformations, focusing attention on the changes in selection rules and in avoided crossings caused by the opposite parity of the proxies with respect to the substituted orbitals [R5,J5].

Using the new approximate analytic parameter-free proxy-SU(3) scheme, we have made [R6,J6,J4,E6,G2] predictions of shape observables for deformed nuclei, namely β and γ deformation variables, and compared them with empirical data and with predictions by relativistic and non-relativistic mean-field theories. Furthermore, simple predictions for the global feature of prolate over oblate dominance and for the locus of the prolate-oblate shape transition have been made and compared with empirical data [R6]. The mechanism leading to the breaking of the particle-hole symmetry has been clarified. It turns out that this mechanism is based on the SU(3) symmetry, the Pauli principle, and the short range of the nucleon-nucleon interaction, without reference to any specific Hamiltonian [R7,J7,G1].

1.4 Outlook

The proxy-SU(3) symmetry can be used for a wide variety of projects. Preliminary results show, for example, into the following directions.

Proxy-SU(3) can provide parameter-free predictions of the regions of shape coexistence, something not achieved by any other model.

Analytic expressions can be derived for B(E2) ratios within the proxy-SU(3) model, free of any free parameters, and/or scaling factors. The predicted B(E2) ratios are in good agreement with the experimental data for deformed
rare earth nuclides [J6,G2]. Spectra can also be determined through the use of three- and/or four/body terms.

An extension of proxy-SU(3) to shells in which protons and neutrons coexist is possible.

2. Publications

2.1 Books

[B1] ``Quantum Mechanics”, D. Bonatsos (Kostarakis, Athens, 2016).Postgraduate textbook, available to students through the ``Evdoxos” system. ISBN 978-618-80913-8-2. 470 pages.

2.2 Articles in Refereed Journals

[R7] ``Prolate over oblate dominance in deformed nuclei as a consequence of the SU(3) symmetry and the Pauli principle”, D. Bonatsos, **Letter to the Editor**, Eur. Phys. J. A 53 (2017) 148 (2 pages). arXiv 1707.03763 [nucl-th].

[R6] ``Analytic predictions for nuclear shapes, the prolate dominance and the prolate-oblate shape transition
in the proxy-SU(3) model”, D. Bonatsos, I. E. Assimakis, N. Minkov, A. Martinou, S. Sarantopoulou,
R. B. Cakirli, R. F. Casten, and K. Blaum, Phys. Rev. C 95 (2017) 064326 (12 pages). arXiv 1706.02321 [nucl-th].

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[R4] ``Bohr Hamiltonian with a deformation-dependent mass term: physical meaning of the free parameter", D. Bonatsos, N. Minkov, and D. Petrellis, J. Phys. G: Nucl. Part. Phys. 42 (2015) 095104 (16 pages). arXiv 1506.07479 [nucl-th].

[R3] ``Analytical solutions for the Bohr Hamiltonian with the Woods-Saxon potential", M. Çapak, , D. Petrellis, B. Gönűl, and D. Bonatsos, J. Phys. G: Nucl. Part. Phys. 42 (2015) 095102 (24 pages). arXiv1506.07444 [nucl-th].

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[R1] ``Octupole deformation in light actinides within an analytic quadrupole octupole axially symmetric model with Davidson potential", D. Bonatsos, A. Martinou, N. Minkov, S. Karampagia, and D. Petrellis, Phys. Rev. C 91 (2015) 054315 (20 pages). arXiv 1504.04837 [nucl-th].

2.3 International Conference Articles Published in Journals

[J7] ``Proxy-SU(3) symmetry in heavy nuclei: Prolate dominance and prolate-oblate shape transition", S. Sarantopoulou, D. Bonatsos, I. E. Assimakis, N. Minkov, A. Martinou, R. B. Cakirli, R. F. Casten, and K. Blaum,
Bulg. J. Phys. (2017) 417-426. arXiv: 1711.05888 [nucl-th]. Proceedings of the Workshop on ``Shapes and Dynamics of Atomic Nuclei: Contemporary Aspects" (SDANCA17, Sofia 2017), ed. N. Minkov.

[J6] ``Parameter free predictions within the proxy-SU(3) model", A. Martinou, D. Bonatsos, I. E. Assimakis, N. Minkov, S. Sarantopoulou, R. B. Cakirli, R. F. Casten, and K. Blaum, Bulg. J. Phys. (2017) 407-416. arXiv: 1711.09201 [nucl-th]. Proceedings of the Workshop on ``Shapes and Dynamics of Atomic Nuclei: Contemporary Aspects" (SDANCA17, Sofia 2017), ed. N. Minkov.

[J5] ``Foundations of the proxy-SU(3) symmetry in heavy nuclei", I. E. Assimakis, D. Bonatsos, N. Minkov, A. Martinou, R. B. Cakirli, R. F. Casten, and K. Blaum, Bulg. J. Phys. (2017) 398-406. arXiv: 1711.08867 [nucl-th]. Proceedings of the Workshop on ``Shapes and Dynamics of Atomic Nuclei: Contemporary Aspects" (SDANCA17, Sofia 2017), ed. N. Minkov.

[J4] ``Proxy-SU(3): A symmetry for heavy nuclei", D. Bonatsos, I. E. Assimakis, N. Minkov, A. Martinou, S. K. Peroulis, S. Sarantopoulou, R. B. Cakirli, R. F. Casten, and K. Blaum, Bulg. J. Phys. (2017) 385-397. arXiv: 1711.08596 [nucl-th]. Proceedings of the Workshop on ``Shapes and Dynamics of Atomic Nuclei: Contemporary Aspects" (SDANCA17, Sofia 2017), ed. N. Minkov.

[J3] ``Various aspects of the Deformation Dependent Mass model of nuclear structure", D. Petrellis, D. Bonatsos, and N. Minkov, Bulg. J. Phys. 42 (2015) 485-493. arXiv:

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[J2] ``Proton-neutron pairs in heavy deformed nuclei", D. Bonatsos, I. E. Assimakis, and A. Martinou, Bulg. J. Phys. 42 (2015) 439-449. arXiv: 1510.01473. Proceedings of the Workshop on ``Shapes and Dynamics of Atomic Nuclei: Contemporary Aspects" (SDANCA15, Sofia 2015), ed. N. Minkov.

[J1] ``Bohr Hamiltonian with deformation-dependent mass", D. Bonatsos, N. Minkov, D. Petrellis, and C. Quesne,
J. Phys.: Conf. Ser. 590 (2015) 012004. Proceedings of the NUBA Conference Series-1: Nuclear Physics and Astrophysics (Adrasan/Antalya 2014).

2.4 Articles in International Conference Proceedings

[C2] ``Prolate-oblate shape transition in neutron-rich heavy rare earths", S. Sarantopoulou, A.Martinou, I. E. Assimakis, N. Minkov, and D. Bonatsos, , in Nuclear Theory '35, Proceedings of the 35th International Workshop on Nuclear Theory (Rila 2016), ed. M. Gaidarov and N. Minkov (Heron Press, Sofia, 2016) 236-243.

[C1] ``Emergence of SU(3) symmetry in heavy deformed nuclei", A. Martinou, I. E. Assimakis, N. Minkov, and D. Bonatsos, , in Nuclear Theory '35, Proceedings of the 35th International Workshop on Nuclear Theory (Rila 2016), ed. M. Gaidarov and N. Minkov (Heron Press, Sofia, 2016) 224-235.

2.5 Presentations at conferences published in electronic form only

[E7] ``Prolate dominance and prolate-oblate shape transition in the proxy-SU(3) model", D. Bonatsos. I. E. Assimakis, N. Minkov, A. Martinou, S. Sarantopoulou, R. B. Cakirli, R. F. Casten, and K. Blaum, in the Proceedings of the 4th Workshop of the Hellenic Institute of Nuclear Physics (HINPw4), Ioannina (5/2017), ed. A. Pakou, http://hinpw4.physics.uoi.gr. arXiv 1706.05844 [nucl-th].

[E6] ``Parameter-independent predictions for shape variables of heavy deformed nuclei in the proxy-SU(3) model", D. Bonatsos. I. E. Assimakis, N. Minkov, A. Martinou, S. Sarantopoulou, R. B. Cakirli, R. F. Casten, and K. Blaum, in the Proceedings of the 4th Workshop of the Hellenic Institute of Nuclear Physics (HINPw4), Ioannina (5/2017), ed. A. Pakou, http://hinpw4.physics.uoi.gr. arXiv 1706.05832 [nucl-th].

[E5] ``Proxy-SU(3) symmetry in heavy nuclei: Foundations", D. Bonatsos. I. E. Assimakis, N. Minkov, A. Martinou, R. B. Cakirli, R. F. Casten, and K. Blaum, , in the Proceedings of the 4th Workshop of the Hellenic Institute of Nuclear Physics (HINPw4), Ioannina (5/2017), ed. A. Pakou, http://hinpw4.physics.uoi.gr. arXiv 1706.05817 [nucl-th].

[E4] ``A symmetry for heavy nuclei: Proxy-SU(3)", D. Bonatsos. I. E. Assimakis, N. Minkov, A. Martinou, R. B. Cakirli, R. F. Casten, and K. Blaum, in the Proceedings of the 4th Workshop of the Hellenic Institute of Nuclear Physics (HINPw4), Ioannina (5/2017), ed. A. Pakou, http://hinpw4.physics.uoi.gr. arXiv 1706.05808 [nucl-th].

[E3] ``New coupling scheme in heavy nuclei", I. E. Assimakis, A. Martinou, and D. Bonatsos, in the Proceedings of the 3rd Hellenic Institute of Nuclear Physics Workshop, Athens (4/2016).

[E2] ``SU(3) symmetry in deformed nuclei", A. Martinou, I. E. Assimakis, and D. Bonatsos, in the Proceedings of the 3rd Hellenic Institute of Nuclear Physics Workshop, Athens (4/2016).

[E1] ``The 2015 U.S. Long Range Plan for Nuclear Science", D. Bonatsos, in the Proceedings of the 3rd Hellenic Institute of Nuclear Physics Workshop, Athens (4/2016).

2.6 Articles in Greek Conference Proceedings

[G2] ``Parameter-independent predictions for nuclear shapes and B(E2) transition rates in the proxy-SU(3) model", A. Martinou, S. Peroulis, D. Bonatsos, I. E. Assimakis, S. Sarantopoulou, N. Minkov, R. B. Cakirli, R. F. Casten, and K. Blaum, to appear in the proceedings of the 26th Annual Symposium of the Hellenic Nuclear Physics Society (HNPS2017), Anavyssos, Greece, 9-10 June 2017, ed. Ch. Tsabaris, R. Vlastou, M. Kokkoris, and D. Patiris. arXiv: 1712.04134 [nucl-th].

[G1] ``A new scheme for heavy nuclei: proxy-SU(3)", D. Bonatsos, R. F. Casten, A. Martinou, I. E. Assimakis, N. Minkov, S. Sarantopoulou, R. B. Cakirli, and K. Blaum, to appear in the proceedings of the 26th Annual Symposium of the Hellenic Nuclear Physics Society (HNPS2017), Anavyssos, Greece, 9-10 June 2017, ed. Ch. Tsabaris, R. Vlastou, M. Kokkoris, and D. Patiris. arXiv: 1712.04126 [nucl-th].

3.1. Ph.D. theses completed

Martinou, Antriana, National Technical U. of Athens (12/2017). ``Nucleon-Nucleon Interaction in Stable and Unstable Nuclei".

Çapak, Mustafa, University of Gaziantep, Gaziantep, Turkey (7/2015). Co-supervised with B. Gönül. ``Special Solutions of the Bohr Hamiltonian with the Woods-|Saxon potential".

Astroparticle physics

Astroparticle physics group

Coordinator: Dr. Christos Markou

Reseacrhers: Dr. E. Tzamariudaki, Dr. A. Belias, Dr. P. Rapidis, Dr. G. Stavropoulos

Under work contract: G. Androulakis, C. Bagatelas, Dr. P. Damianos, Dr. C. Manolopoulos, E. Kappos, Dr. K. Balasi, Dr. N. Maragos

Ph.D. Students: E. Drakopoulou, K. Pikounis, D. Tzanetatos, G. Polydefki, V. Panagopoulos

Postgraduate Students: A. Sinopoulou, D. Stavropoulos

Techical and Support personnel: P.Tsagkli, G.Kiskiras, A.Vougioukas, S.Bakou.

The main interest of the astroparticle physics group of the Institute of Nuclear and Particle Physics (INPP) is the study of neutrinos from cosmic accelerators. The study of cosmic neutrinos, offers significant advantages towards answering basic questions about the origin and nature of the cosmic rays. Neutrinos, being neutral, are not deflected by interstellar magnetic fields and, unlike photons, are not significantly absorbed by any intervening matter. Thus they point back to their sources over all energy ranges and distance scales, and hence are uniquely valuable as cosmic messengers. In addition, the detection of astrophysical high energy neutrinos would shed light on the question whether the sources of high energy gamma rays observed by the HESS telescope are due to electromagnetic or hadronic processes.

The INPP astroparticle physics group is a member of the KM3NeT collaboration. KM3NeT is a distributed Research Infrastructure, member of the ESFRI Road Map that will consist of a network of deep-sea neutrino telescopes in the Mediterranean Sea with user ports for Earth and Sea sciences. Once completed, the telescopes will have detector volumes between megaton and several cubic kilometers of clear sea water. Located in the deepest seas of the Mediterranean, KM3NeT will open a new window on our Universe, but also contribute to the research of the properties of the elusive neutrino particles. With the ARCA telescope, KM3NeT scientists will search for neutrinos from distant astrophysical sources such as supernovae, gamma ray bursts or colliding stars. The ORCA telescope is the instrument for studying neutrino properties exploiting neutrinos generated in the Earth's atmosphere.

During the period 2015 - 2017, the group has been active in the construction, testing, and validation of the KM3NeT detectors and individual components, physics analyses and studies, design and development of the Power Board for DOMs, development of timing and communication protocols (White Rabbit), governance and management. In addition, 2015 was the year in which the GRBNeT project was completed as is detailed below.

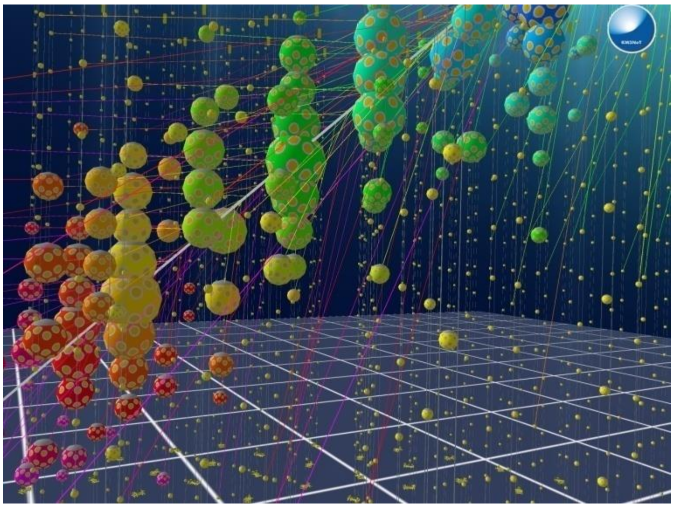

Figure 1: An artists' view of an event as it will be seen from the KM3NeT telescopes

KM3NeT management and governance

In September 2016, Dr. C. Markou was elected as head of the Institution Board (IB) of KM3NeT, for a term of 2 years. As such, among other duties, he represents the KM3NeT IB to the Resources Review Board, and the Scientific and Technical Advisory Committee of the experiment. Dr. C. Markou and Dr. E. Tzamariudaki are members of the KM3NeT Pubication committee. In addition Dr. Tzamariudaki participates in the Conference Committee of the experiment. G. Androulakis is the Quality Assurance/Quality control manager of KM3NeT, member of the Management Team and the Steering Committee of the experiment.

KM3NeT construction

DOM Lab

The group has established a DOM integration, validation and testing facility in the premises of INPP in 2016. The DOM lab has been funded exclusively through internal funds. It was completed in record time (compared to other similar labs in KM3NeT), and has been operational in late 2016. Work on the first DOMs started immediately, and the first 18 DOMs corresponding to a full Detection Unit of KM3NeT were completed in 2017. The lab continues full scale integration of DOMs. Currently the lab employs 2 FTE of skilled personnel, with additional help from other group members as the need arises. This facility is expected to continue its operation in the coming years. In 2018, the construction for Phase-1 is expected to finish, with full scale production for Phase-2 starting immediately afterwards.

Figure 2: A DOM completed in the INPP DOM lab

Additional testing and validation efforts are ongoing concerning the high-pressure testing of the DOM penetrators which are used for powering the DOMs and for data transfer from the DOMs. These are done using a high-pressure testing chamber, capable of sustaining pressure up to 600 bars. These tests are done for a large fraction of the KM3NeT DOM penetrators, as the only other similar facility is in NIKHEF, Amsterdam.

The group has also undertaken the calibration of the DOM central logic boards (CLBs), an activity which is expected to continue over the coming years, involving the majority of the corresponding boards used in KM3NeT.

Electronics

In 2015, 2016 and 2017, Dr.A. Belias continued his involvement on control and timing network, of deep-sea network and on-shore station. Continued work on the Power Board for the OM (FIDES analysis for mass production) and on digital tilt- and compass-boards for the OM, designed in the group, at the former NESTOR Instituteand the design of a stand-alone test system after mass production and prior to deployment in 2016.

Physics analyses

Several group members have been active in physics analyses, especially for High energy neutrinos to be studied by KM3NeT/ARCA. Most of these were carried out in the context of Ph.D., M.Sc. or diploma theses. These are briefly outlined below.

"Muon and Neutrino Energy Reconstruction for KM3NeT", E. Drakopoloulou, Ph.D. Thesis (2016), Supervisors: E. Tzamariudaki, C. Markou

Since the accuracy of the reconstructed muon and neutrino direction will be decisive for the observation of astrophysical neutrino sources, improvements to the existing muon reconstruction algorithm were made and quality selection criteria were developed to reject poorly reconstructed tracks. An angular resolution of 0.5 degrees (median) and 0.2 degrees was obtained for TeV and PeV energy muons, respectively. The muon and neutrino energy were reconstructed by employing a Neural Network with appropriate input variables. An estimate of the muon and neutrino energy was made for events crossing the detector volume, and a lower limit for the muon energy was provided when the reconstructed muon passes outside the instrumented volume. The energy resolution achieved with this method is approximately 0.25 in $\log_{10} E_{\mu}$ for muons at the TeV energy range.

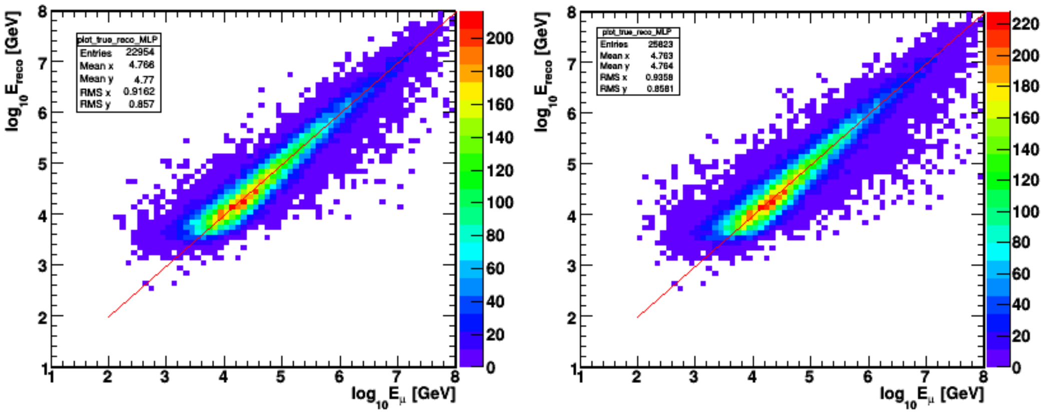

Figure 3: The reconstructed energy ($\log_{10}E_{reco}$) with respect to the MC muon energy ($\log_{10} E_{\mu}$) for events that satisfy a containment selection (left plot) and for all reconstructed events (right plot)

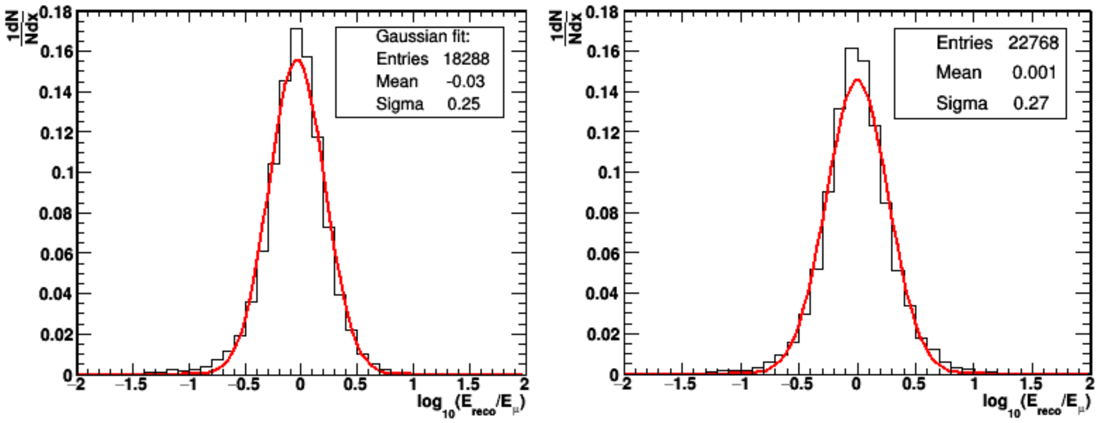

Figure 4: The distribution of $\log_{10}(E_{reco}$-$E_{\mu})$ for events that satisfy the containment selection with E_{μ}> 1 TeV (left plot) and events with E_{μ}> 10 TeV (right plot). The y axis corresponds to 1/NdN/dx where $x = \log_{10}(E_{reco}$-$E_{\mu})$.

This method was further used to derive the sensitivity and discovery potential of the KM3NeT neutrino telescope for the detection of high energy neutrinos from astrophysical sources.

"Neutrino detection with an underwater neutrino telescope in the Mediterranean Sea", Ph.D. candidate, Kostas Pikounis, Supervisors: E. Tzamariudaki, C. Markou

Kostas Pikounis is involved in MC simulation studies of the ARCA telescope targeting the improvement of the discovery potential for astrophysical neutrinos. He has been working on creating two tools based on machine learning algorithms (Boosted Decision Trees), one for the differentiation of track-like and shower-like events and the other for the differentiation between starting track events and through going events in ARCA. By combining these tools, a High Energy Starting Events (HESE) analysis with the ARCA telescope is possible. A study of the discovery potential of the ARCA telescope for a diffuse flux of astrophysical neutrinos using HESE showed that ARCA is expected to make a 5σ discovery with a 50% and a 90% probability of the astrophysical flux measured by IceCube in less than 0.5 and 0.8 years, respectively.

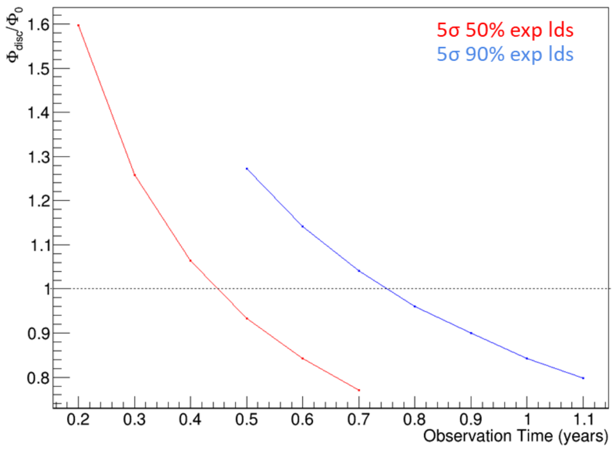

Figure 5: Ratio of the Discovery flux factor over the flux factor of the astrophysical flux reported by IceCube with respect to the observation time in years.

Kostas Pikounis has also been involved in the simulation of atmospheric showers using the CORSIKA program, as a large fraction of down going atmospheric neutrinos could be identified by the accompanying muons created at the same atmospheric shower (self-veto effect). Extensive studies have been conducted to evaluate the contribution of the prompt component of atmospheric neutrinos for the various models used in CORSIKA and comparisons with theoretical models were made.

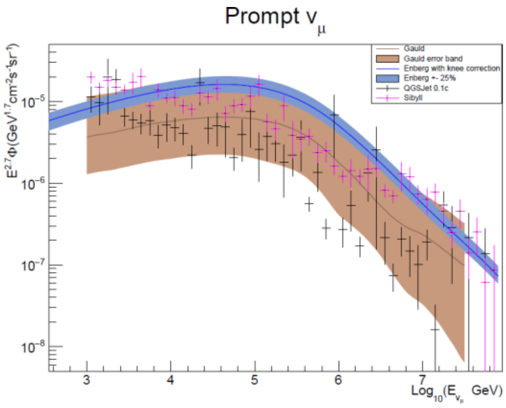

Figure 6: Theoretical models for the prompt atmospheric neutrino flux, Enberg with the knee correction (blue band) and Gauld et al. (brown band) are shown. Points as derived by CORSIKA simulated events are overlaid. HE interaction model used: QGSJet 01c (black) and Sibyll 2.3 (Magenta).

The sample of simulated events has been used to assess the magnitude of the self-veto effect for ARCA. Using only the ν_μCC channel, since the contribution of atmospheric muon neutrinos is much greater than that of the electron neutrinos, it was found that practically all atmospheric neutrinos accompanied by muons can be identified and can be rejected from the final sample. This resulted in a decrease of 25% in the time needed for ARCA to make a discovery using only High Energy Starting Tracks. An equivalent reduction can be expected for the HESE analysis.

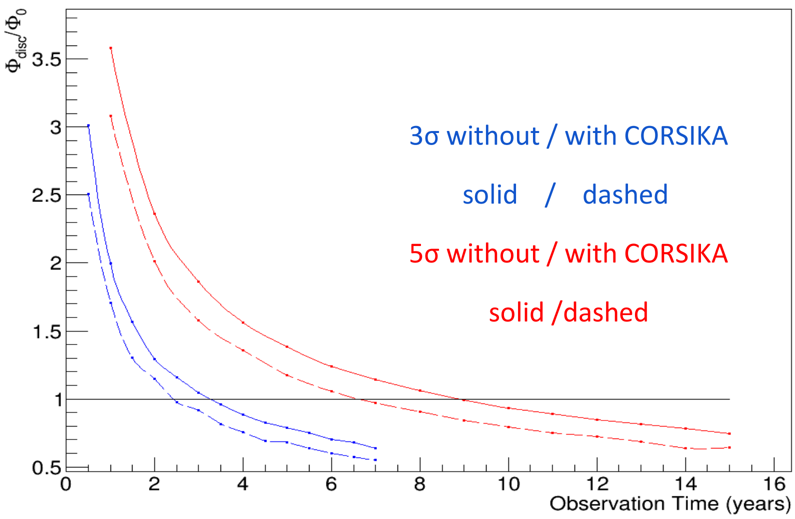

Figure 7: Ratio of the Discovery flux factor over the flux factor of the astrophysical flux reported by IceCube with respect to the observation time in years. The events used belong to the starting tracks sample. Solid lines: only atmospheric neutrinos used as background, dashed lines: both the atmospheric neutrino sample and CORSIKA simulated events samples were used for the background.

3 more PhD. candidates have recently started their research work supervised by members of the group. They are Dimitris Tzanetatos, Georgia Polydefki and Vassilis Panagopoulos. Their work involves studies of the first real data of the ARCA detector (DT), and studies concerning the feasibility of acoustic detection of ultra-high energy neutrinos (GP and VP).

“Studies using alternative configurations of the KM3NeT-ARCA detector for the detection of high energy neutrinos”, Anna Sinopoulou, MSc Thesis, Supervisor E. Tzamariudaki

Alternative detector configurations for the KM3NeT/ARCA detector have been studied focusing on the discovery of a diffuse astrophysical neutrino flux using muon tracks. The discovery by IceCube of a diffuse flux of extraterrestrial neutrinos extending to PeV energies and the maturity of the KM3NeT reconstruction algorithms, motivate reconsidering the optimal horizontal spacing for the KM3NeT-ARCA detector. In addition, in order to be sensitive to very high energy (E > 1 PeV) neutrinos originating from violent extraterrestrial and extragalactic phenomena it is needed to increase the volume of the “existing” neutrino telescopes. The excellent angular resolution of the reconstruction in KM3NeT prompts for a study of sparser geometries in order to fully explore the detector potential. The advantage of having a sparser detector configuration is the increase in effective area (Fig.1) which in turn is expected to result to a better sensitivity and discovery potential for neutrinos at higher energies (Fig.2). Three alternative detector configurations corresponding to sparser detectors have been studied. The angular and energy resolutions have been investigated and were compared to the ones using the standard KM3NeT-ARCA detector. Studies on the sensitivity and the discovery potential were made using the most up-to-date IceCube astrophysical neutrino flux and for comparison, also with the astrophysical neutrino flux used for the Letter of Intent of the KM3NeT collaboration. Taking into account the detector response in all geometries studied, it was concluded that the most ”efficient” geometry for detecting very high energy neutrinos was the geometry with a distance of 150 m between the detection units because of its gain in effective area, sensitivity and discovery potential comparing to the standard and the alternative geometry of 120m distance between the strings (Fig.1) and of its better reconstruction quality and angular resolution comparing to the alternative geometry of 180mdistance between the strings.

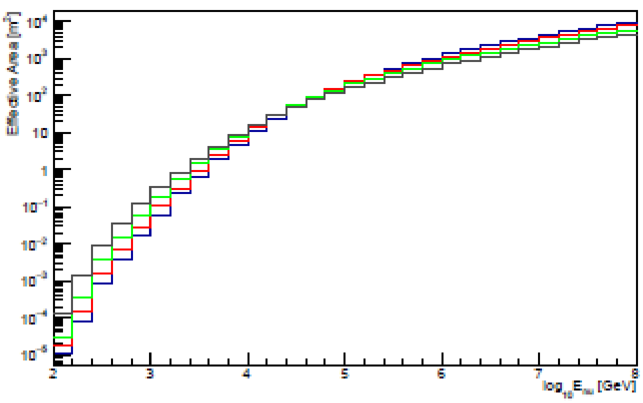

Fig 8. The neutrino effective area as a function of the neutrino energy for the reconstructed events fulfilling the quality cuts, for the detector configurations with 90 m - standard geometry (black), 120 m (green), 150 m (red), 180 m (blue) distance between the detection units.

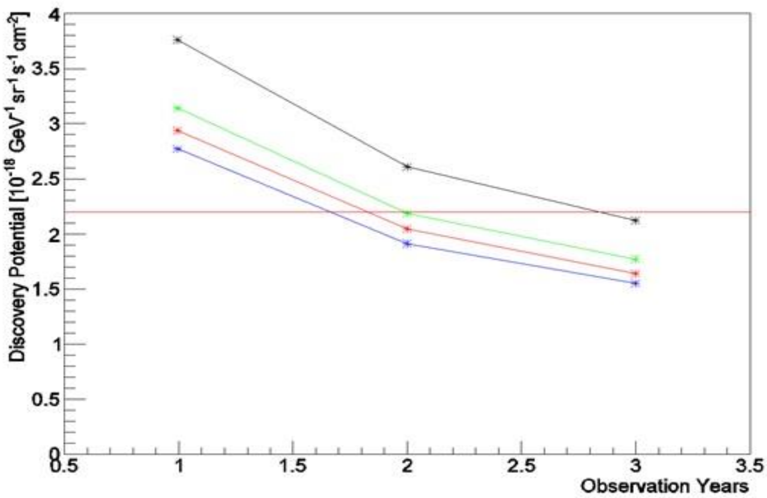

Fig 9. The discovery potential as a function of the observation time using theIceCube flux. The estimation of the discovery potential is represented with black for the standard KM3NeT geometry, with green for the 120 m alternative geometry, with red for the 150 m alternative geometry and with blue for the 180 m alternative geometry.

"Depth dependence of the atmospheric muon rate using KM3NeT/ARCA data", D. Stavropoulos, Diploma Thesis, Supervisor E Tzamariudaki

A study of the detection frequency of atmospheric muons as a function of depth was carried out using the data collected by the first two detection units (DUs) of KM3NeT/ARCA. Taking advantage of the multi-PMT Digital Optical Modules (DOMs) of the KM3NeT neutrino telescope, atmospheric muon detection can be achieved by using time coincidences between the PMT hits in the same DOM. Optical noise originating from the radioactive decays of ^{40}K in sea water can be completely suppressed by applying the requirement of a large number (≥ 8) of PMT hits in the same DOM within a certain time interval (Fig. 1 left). No track reconstruction has been performed at this stage and the DOM position has been used as an indication of the sea depth (Fig. 1 right).

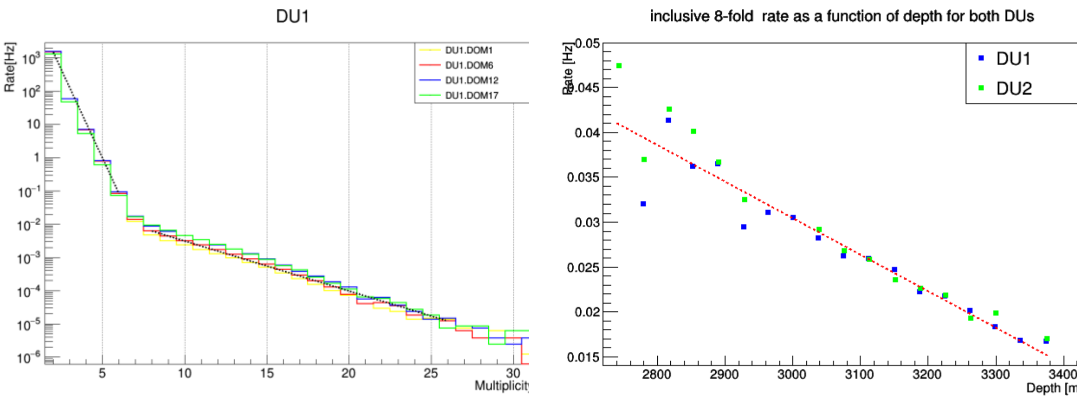

Figure 10: Left: Coincidence rate as a function of the coincidence multiplicity for selected DOMs of the 1st DU. Right: Inclusive 8-fold coincidence rate as a function of depth for both DUs.

"Computer Modeling of Acoustic Waves in the Deep Sea",M.Sc. Thesis, Mariana Teta, Supervisor: A. Belias

GRBNeT

In 2015, the GRBNeT project was completed. It was a project funded by the THALES initiative of the GSRT with a total budget of 540,000 euros. Dr. C. Markou was the PI of GRBNeT, a collaboration of INPP/NCSR Demokritos, the Physics Department of the University of Athens and the Hellenic Centre for Marine Research. The aim of GRBNeT was the design, development, construction and deployment of an autonomous detector for high energy neutrinos emitted by astrophysical objects like Gamma-Ray-Bursts (GRBs). As the detector had to operate for several months with power and data collection autonomy, dedicated very low power electronics had to be designed and built for the experiment purposes. The detector was built and deployed in the sea west of Pylos, at 3000m depth. The detector operated for several months before shutting down. The GRBNeT detector has been recovered and the recorded data have been processed. Details on the project can be found in http://www.neutrinoburst.gr.

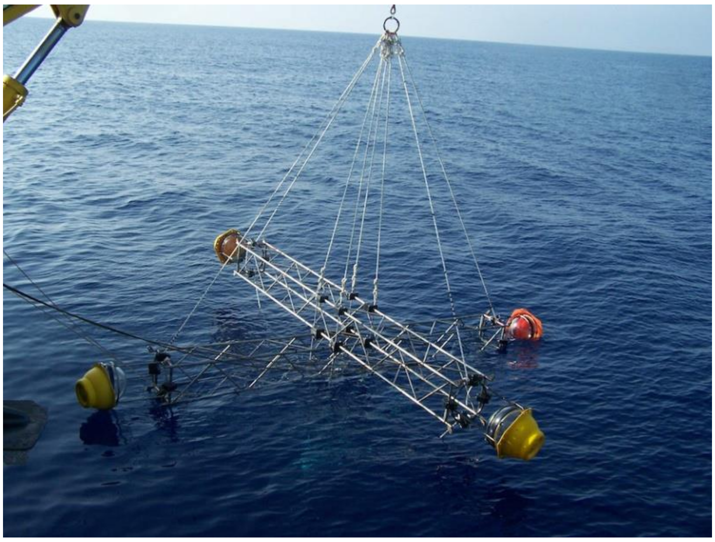

Figure 11: Deployment of the mechanical structure of GRBNeT.

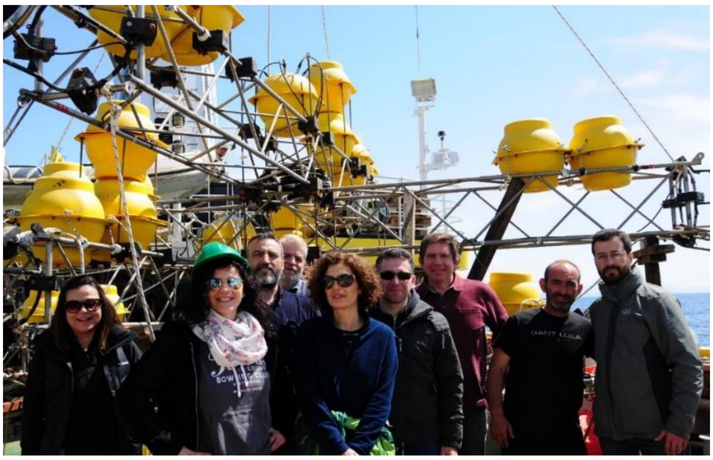

Figure 12: Photo of the INPP group, taken after the successful recovery of the GRBNeT

KM3NeT - INFRADEV

In 2017 the KM3NeT-INFRADEV project started, funded by H2020 for a period of 3 years. In the context of this project, Dr. E. Tzamariudaki is the coordinator of WorkPackage 9, on "Technology transfer" and Dr. C. Markou is the Coordinator of WorkPackage 10 on "Zero carbon footprint". Members of the group are also involved in most other WPs of the project.

KM3NeT Meetings

The astroparticle physics group has hosted 3 major meetings of KM3NeT:

- In October 2016, a Software and Computing meeting was held in INPP with the participation of around 30 scientists from KM3NeT.
- In February 2017, the KM3NeT Collaboration meeting was held in Demokritos, with the participation of ~100 KM3NeT members.

Figure 13: The KM3NeT collaboration in a recent meeting in INPP

- 18-20/9/2017, a 3 day workshop on training of internal auditors for quality management systems, QA/QC working group meeting at INPP
- 20/11/2017 Scientific and Technical Advisory committee meeting
- In December 2017, a 2,5 day workshop on User ports related to the Workpackage 8 of the KM3NeT-INFRADEV project.
- In December 2017, a workshop on acoustic detection of high energy neutrinos with participation of scientists from Greece, Italy, France, the Netherlands, Germany and Russia.

Kalamata Annex

As the main building (Old Gymansio) in Pylos had to be vacated by 2018, an agreement with the Town of Kalamata was reached, where the main activities of INPP would be housed in the Zoumbouleio Megaron, a spectacular early 20th-century building in the center of Kalamata. After an MoU with the municipality of Kalamata was signed in mid-2016, we have moved temporarily to a building provided by the Mayor of Kalamata waiting for the Zoumbouleio to get ready. In due time, all the land operations of KM3NeT in the area will be housed in Kalamata, as well as additional activities from other Institutes of NCSR Demokritos.

KRIPIS

2015 was the concluding year of the 3-year KRIPIS I project. Two activities were funded, led by Dr. A. Belias and Dr. G. Stavropoulos respectively. These are described - outlined below.

Dr. A. Belias led the activity on the **characterization of control and monitoring of switch-based timing network based on White Rabbit** for deep-sea Neutrino Telescopes. Characterization of OM with large hemispherical PMT and considerations on re-design of KM3NeT OM for possible use in other experiments.

The second activity is reported below.

A method of measuring the optical parameters of deep-sea water - G. Stavropoulos

The observation of high energy neutrinos of astrophysical origin in underwater neutrino telescopes, such as KM3NeT, relies mainly on the charged current interactions of muon-neutrinos with sea water or underlying rock. The produced high-energy muons travel faster than the speed of light in water emitting Cherenkov light that provides the primary observation mode of such a detector. Accurate knowledge of the optical properties of the sea water is important for the design and performance evaluation of an underwater neutrino telescope. The geometrical parameters of such a telescope and its angular resolution are affected by the optical absorption and scattering of the Cherenkov radiation. In sum, the energy and angular resolution of the detector depends on the optical properties of the sea-water and a precise knowledge of them is required for a proper interpretation of the experimental data.

A new experimental method to measure in situ the optical properties of the deep-sea water is being studied in the frame of the KRIPIS project. The experimentally measured and the simulated arrival time distributions were used to apply a χ^2 minimization process for the estimation of the aforementioned optical parameters, using a re-weighting method for the propagation in the parameters space. This method relies on the fact that, given the recorded track history of a "detected" photon, a quantity proportional to the probability of a photon to follow the specific track as a function of the optical parameters can be calculated.

To test the reliability of the method, a MC sample of events was produced, considered as the set of experimentally recorded events (hereafter pseudo-data), with parameters: $L_a =$

$73m$, $L_s = 56.4m$, $p = 0.21$, $a_{Mie} = 0.75$ and a second MC sample of events, considered as the simulated events, with parameters: $L_a = 65m$, $L_s = 48.4m$, $p = 0.17$,$a_{Mie} = 0.924$. In all samples of events a_{Rayl} was fixed toa_{Rayl}=0.853, since it is a well-known factor, attributable to the anisotropy of water molecules, and additionally its variations have insignificant impact in the resulting arrival time distributions. Using the re-weighting technique, a χ^2 fit was applied of the simulated arrival time distributions to the corresponding ones from the pseudo-data and a set of estimated parameters was calculated. This set of parameters was consequently used to produce a new set of MC events and repeat the χ^2 fit procedure on the pseudo-data as previously described. This process was repeated until the difference of each estimated parameters between the last two fits, divided by its error calculated in the last fit is smaller than 1. The procedure converged after five iterations. The "real" parameters are well estimated from the final fit with the following uncertainties: δp=0.0019 (0.9%), δL_s=1.34 m (2.4%), δL_a=2.14 m (2.9%) and δa_{Mie}=0.0023 (0.3%).

The experimental apparatus consisted of four, 5 m long titanium girders, attached to each other to form a linear and robust structure (**Figure 14**4). One of the girders had a 17" diameter optical module (OM) attached, inside this OM three pairs of laser diodes were placed, emitting at wavelengths 405 nm, 450 nm and 520 nm. At the other end of the same girder a field stop was placed in order to avoid the exposure of the detectors to direct light. The last girder which was equipped with the optical module that housed the four Hamamatsu photomultipliers was finally attached.

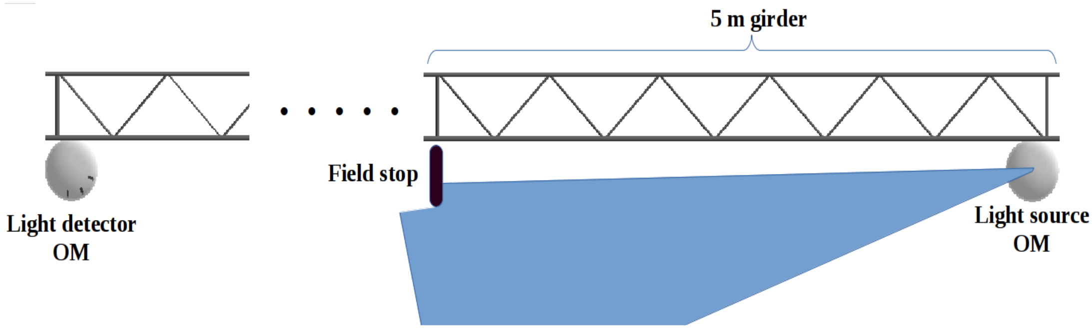

Figure 14The experimental setup

The electronic system of the experimental apparatus consists of two parts. One is the laser source system inside the light source OM that drives the six laser diodes, two laser diodes at different angles for each of the three wavelengths, the other is the main system that converts the signals from the PMT sensors, stores the data on external memory and controls the laser source system. The main system is housed in the light detector OM. The master controller of the main system is a Xilinx Spartan-6 FPGA. The main controller (FPGA) sends a signal to the laser source system, via a cable for deep sea applications that chooses which laser diode to drive. After it's triggered the laser controller drives the laser diodes to emit 10 ns light pulse. At this point the main controller starts a timer counter. When scattered photons are detected by any of the PMT modules a timestamp measurement occurs. Time measurement is converted to digital data and is sent to an AVR microcontroller that stores the data to an SD memory card. A USB connector was mounted on the light detector OM to retrieve the data stored in the SD memory card. Both systems where powered by d-type batteries. The experimental apparatus was tested in detail in the lab, before deployment. The site chosen for the deployment of the detector is the western side of Pylos (36^0 31' B and 21^0 26' A), 40 km from shore at a sea depth of ~4500 m. On October 28, 2015 the Aegeon ship of the Hellenic Center for Marine Research was used in order to perform the deployment of the experimental apparatus.

Three deployments of the apparatus were attempted, with the distance between laser and PMT OMs to be ~10m, ~15m and ~20m respectively. In each deployment the apparatus was taking data for 1 hour in total, at a depth of ~3500m.

The results of a preliminary fit to the experimental data for a 405 nm laser is shown in the following figures.

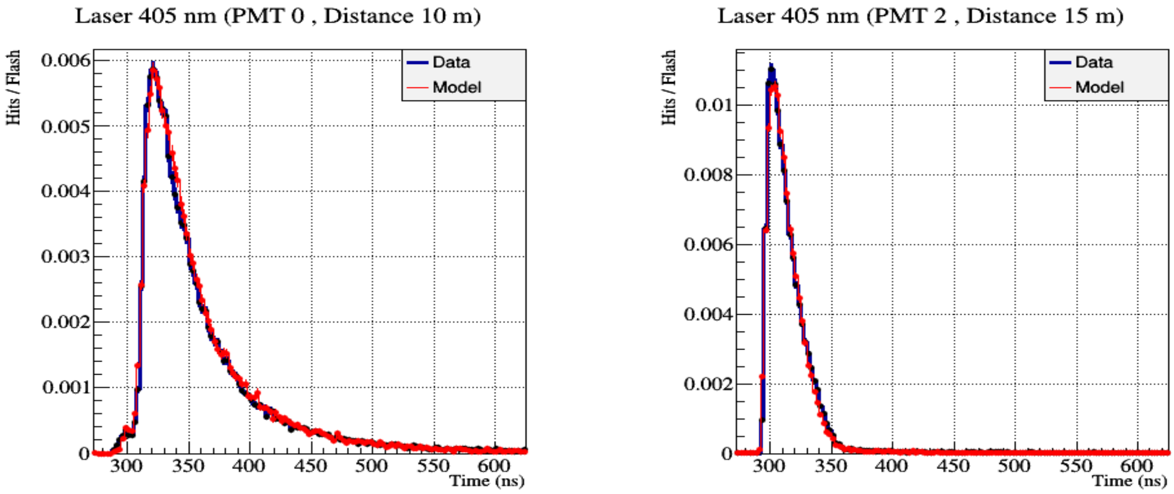

Figure 15:Photons per laser pulse (405 nm) detected at photomultipliers 0 and 2 at distances 10 and 15 m respectively (blue line). The theoretical model (simulation) fitted to the experimental data (red line).

	values	Uncertainty (1σ)	Correlation matrix
L_a	28.6	0.1	1.000 0.080 -0.499 -0.101
L_s	150.6	1.4	0.080 1.000 -0.115 -0.093
p	56 %	1 %	-0.499 -0.115 1.000 0.752
a_{Mie}	0.203	0.002	-0.101 -0.093 0.752 1.000

Table 1:The fit results for a 405 nm laser.

Publications:

K.G. Balasi, "An autonomous underwater telescope for measuring the scattering of light in the deep sea", J.Phys.Conf.Ser.718 (2016) no.6, 062002.

N. Maragos, "Measurement of light scattering in deep sea", EPJ Web Conf. 116 (2016) 06009.

Additional Activities

In 2015, Dr. A. Belias was a visiting fellow at APC, Paris: Studies on synchronicity of OMs and involvement in the set-up of a water-tank facility at APC for the characterization and cross-calibration of OM with large hemispherical PMT and KM3NeT OM with small PMTs. In 2016, he followed up results from water-tank facility at APC.

In 2015 Dr. A. Belias worked in the technical coordination and Cherenkov detectors for the PANDA experiment at FAIR. This work continued in 2016 and 2017.

Future Plans

The Astroparticle Physics group will continue the work in KM3NeT, with emphasis in the construction and operation of the detector according to the current planning as detailed by the KM3NeT MoU. In addition, we will be exploiting the possibility to initiate activities in the SW Peloponnese site in order to establish a KM3NeT infrastructure based on acoustic detection techniques in the coming years.

Publications (including conference proceedings)

KM3NeT Publications

1) The prototype detection unit of the KM3NeT detector
By KM3NeT Collaboration (S. Adrián-Martínez et al.). arXiv:1510.01561 [astro-ph.IM]. 10.1140/epjc/s10052-015-3868-9. Eur.Phys.J. C76 (2016) no.2, 54.
2)Intrinsic limits on resolutions in muon- and electron-neutrino charged-current events in the KM3NeT/ORCA detector
By S. Adrián-Martínez et al..,arXiv:1612.05621 [physics.ins-det].10.1007/JHEP05(2017)008. JHEP 1705 (2017) 008.
3) Letter of intent for KM3NeT 2.0
By KM3NeT Collaboration (S. Adrian-Martinez et al.).
arXiv:1601.07459 [astro-ph.IM]. 10.1088/0954-3899/43/8/084001.
J.Phys. G43 (2016) no.8, 084001.
4)“Energy reconstruction of high energy muon and neutrino events in KM3NeT",
E. Drakopoulou et al. [KM3NeT Collaboration]. DOI:10.1051/epjconf/201611602001 EPJ Web Conf., 116, 02001 (2016).
5) “Muon and neutrino energy reconstruction for KM3NeT”
E. Drakopoulou et al. [KM3NeT Collaboration]. DOI: 10.1051/epjconf/201612105009 EPJ Web Conf. 121 (2016) 05009
6) “Muon track reconstruction and muon energy estimate in the KM3NeT/ARCA detector”
A.Trovato, E. Drakopoulou, P.Sapienza [KM3NeT Collaboration].
DOI: 10.22323/1.236.1114, PoS ICRC2015 (2016) 1114
7) Using IKAROS as a data transfer and management utility within the KM3NeT computing model"
C. Filippidis, Y. Cotronis and C. Markou. DOI:10.1051/epjconf/201611607001 EPJ Web Conf. 116,07001 (2016).
8) A study on implementing a multithreaded version of the SIRENE detector simulationsoftware for high energy neutrinos", P. Giannakopoulos et al..DOI:10.1051/epjconf/201611607005, EPJ Web Conf. 116, 07005 (2016)
9)Muon and Neutrino Energy Reconstruction for KM3NeT"
E. Drakopoulou et al. [KM3NeT Collaboration]. PoS NEUTEL 2015, 071 (2015).
10)T.Heid, C.James, K.Pikounis for the KM3NeT Collaboration “Self-veto approaches to reject atmospheric neutrinos in KM3NeT/ARCA”, PoS ICRC2015 (2016)

GRBNeT Publications

1)GRBNeT A prototype for an autonomous underwater neutrino detector"
K. Pikouniset al.. DOI:10.1051/epjconf/201611609004, EPJ Web Conf. 116, 09004 (2016).
2)Digital and Analog Electronics for an autonomous, deep-sea, Gamma Ray Burst Neutrino prototype detector", K. Manolopoulos, A. Belias, C. Markou, P. Rapidis and E. Kappos. DOI:10.1051/epjconf/201611605010, EPJ Web Conf. 116, 05010 (2016).

PANDA Publications (A. Belias)

1) Tests and developments of the PANDA Endcap Disc DIRC
By E. Etzelmülleret al..10.1088/1748-0221/11/04/C04014. JINST 11 (2016) no.04, C04014.
2) The PANDA Endcap Disc DIRC
By K. Föhlet al..10.1088/1748-0221/13/02/C02002. JINST 13 (2018) no.02, C02002.
3) Recent developments with microchannel-plate PMTs
By A. Lehmann et al..10.1016/j.nima.2016.12.063. Nucl.Instrum.Meth. A876 (2017) 42-47.
4) Tremendously increased lifetime of MCP-PMTs
By A. Lehmann et al..10.1016/j.nima.2016.05.017. Nucl.Instrum.Meth. A845 (2017) 570-574.
5) Feasibility study for the measurement of πN transition distribution amplitudes at $\overline P$ANDA in $\bar{p}p\to J/\psi\pi^0$
By PANDA Collaboration (B. Singh et al.). arXiv:1610.02149 [nucl-ex].
10.1103/PhysRevD.95.032003. Phys.Rev. D95 (2017) no.3, 032003.
6) Feasibility studies of time-like proton electromagnetic form factors at $\overline{\rm P}$ANDA at FAIR
By PANDA Collaboration (B. Singh et al.). arXiv:1606.01118 [hep-ex]. 10.1140/epja/i2016-16325-5.Eur.Phys.J. A52 (2016) no.10, 325.
7) The PANDA Barrel DIRC
By R. Dzhygadloet al..10.1088/1748-0221/11/05/C05013. JINST 11 (2016) no.05, C05013.
8) Lifetime of MCP-PMTs
By A. Lehmann et al..10.1088/1748-0221/11/05/C05009. JINST 11 (2016) no.05, C05009.
9) Resolution changes of MCP-PMTs in magnetic fields
By J. Rieke et al..10.1088/1748-0221/11/05/C05002. JINST 11 (2016) no.05, C05002.
10) Tests and developments of the PANDA Endcap Disc DIRC
By E. Etzelmülleret al..10.1088/1748-0221/11/04/C04014. JINST 11 (2016) no.04, C04014.
11) Particle identification algorithms for the PANDA Endcap Disc DIRC
By M.. Schmidt et al..10.1088/1748-0221/12/12/C12051. JINST 12 (2017) no.12, C12051.
12) The Endcap Disc DIRC of PANDA
By M. Dürenet al..10.1016/j.nima.2017.02.077. Nucl.Instrum.Meth. A876 (2017) 198-201.
13) Recent developments with microchannel-plate PMTs
By A. Lehmann et al..10.1016/j.nima.2016.12.063. Nucl.Instrum.Meth. A876 (2017) 42-47.
14) Technical Design Report for the PANDA Barrel DIRC Detector
By PANDA Collaboration (B. Singh et al.). arXiv:1710.00684 [physics.ins-det].
15) The PANDA DIRC detectors at FAIR
By C. Schwarz et al.. arXiv:1707.09269 [physics.ins-det]. 10.1088/1748-0221/12/07/C07006. JINST 12 (2017) no.07, C07006.
16) Tremendously increased lifetime of MCP-PMTs
By A. Lehmann et al..10.1016/j.nima.2016.05.017. Nucl.Instrum.Meth. A845 (2017) 570-574.
17) Feasibility study for the measurement of πN transition distribution amplitudes at $\overline P$ANDA in $\bar{p}p\to J/\psi\pi^0$
By PANDA Collaboration (B. Singh et al.). arXiv:1610.02149 [nucl-ex]
10.1103/PhysRevD.95.032003. Phys.Rev. D95 (2017) no.3, 032003.

Other Publications

1) "Hydrography, circulation and mixing at the Calypso Deep (the deepest Mediterranean trough) during 2006-2009", H. Kontoyiannis, A. Belias, et al, DOI: 10.1175/JPO-D-15-0198.1 Journal of Physical Oceanography.

Applications

1) Radioactive Source Localization by a Network of CZT Sensors

In the new era of homeland security there is a growing concern regarding the possession and the potential use of radiological materials by terrorist groups usually in the form of a radiological dispersion device *(RDD),* also known as *"dirty bomb"*. Since the defended areas from such a threat may not have specific entrance and exit points, the problem of how to localize and identify a radioactive source in an open area should be investigated. The detection has to overcome a variety of uncontrollable factors, such as the presence of benign sources, time and space varying background noise, and obstacles that may occlude signal from sources.

We tackled the above complicated problem using a network of small form factor spectroscopic detectors realized using CZT crystals. This network was used as a verification platform for a set of localization algorithms. The capabilities of the above CZT network to localize radioactive sources were investigated using simulated data. Then a series of verification tests were performed using experimental data collected by a locally developed data acquisition system from the CZT sensor network realized in our lab (Figure 1). The localization algorithms were based on both analytical calculations and machine learning techniques, such as Neural Networks (MLP) and Boosted Decision Trees (BDT). The estimated accuracy was of the order of 2%-10% depending on the exposure time.

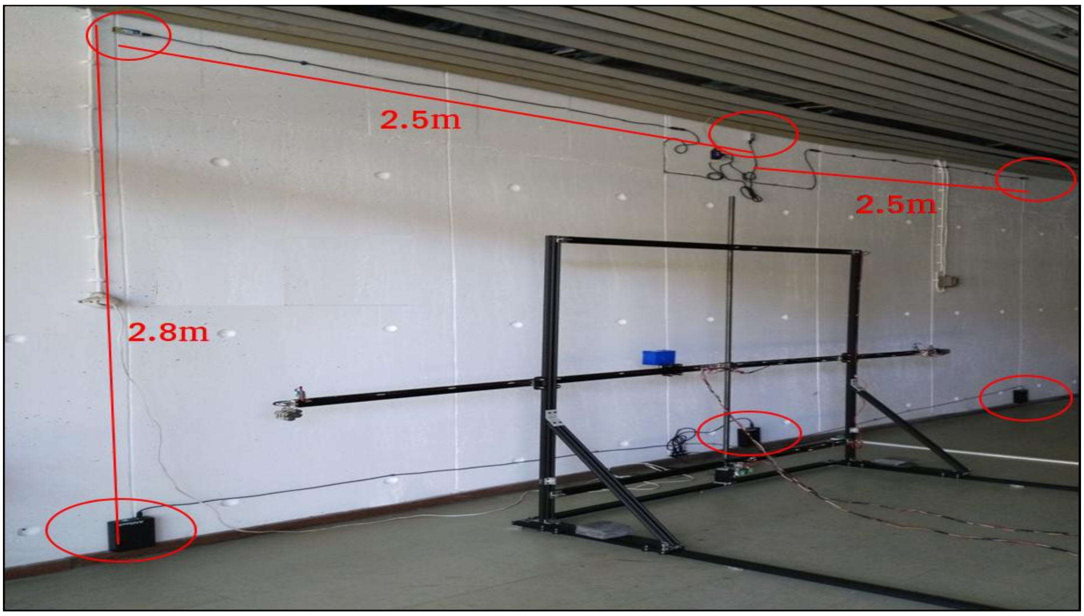

Figure 1: Experimental Setup of the CZT network (red circles). The energy response of the sensors has been recorded when a radioactive source i.e. ^{137}Cs (blue box) has been placed in various position using the 3D moving frame.

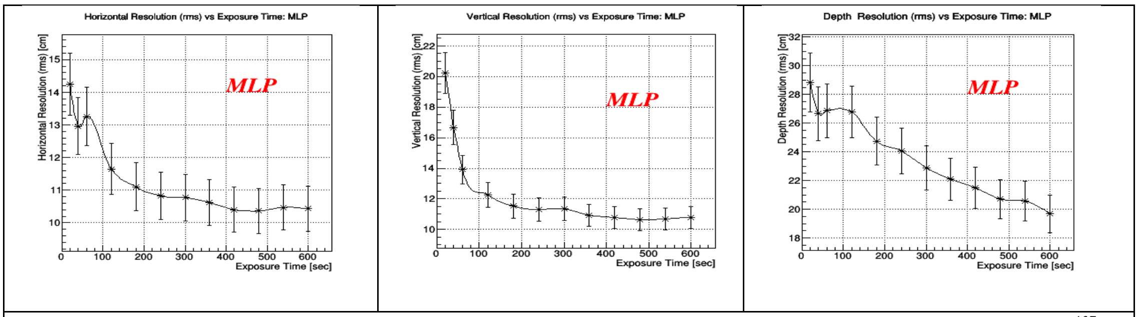

Figure.2: *Experimental CZT network horizontal l (left), vertical (middle), depth (right) precision localization for a ^{137}Cs Source (~7MBq) at 0.8m from sensor plain as a function of the exposure time (in seconds)*

The project is funded by NATO SfP-984705 program. More information can be found in: http://www.senera.org/

Conferences:

- SORMA 2016(2016 IEEE Symposium on Radiation Measurements and Applications), University of California, Berkeley
- *IEEE 2016* NSS/MIC, Strasburg, France, https://event.crowdcompass.com/2016-nss-mic/activity/6MFjqc460k → N08-36 - A Radiation Sensor Network with the Abil, zity to Localize the Radiation Source

Partners:

- Greek Atomic Energy Commission (GAEC), P. Grigoriou & Neapoleos, 15341, Agia Paraskevi, Athens, Greece
- Hellenic Army Academy (HAA), Varis - Koropiou Avenue, 16673 Vari, Greece
- Hellenic Army General Staff R&IT Directorate (HAGS/R&IT Dir), Mesogeion 227-231, 15561 Holargos, Greece

2) Low-Cost Carbon Nanotubes Photodetectors (CNT)

Investigate the fabrication of ultraviolet (UV) and infrared (IR) solid-state photodetectors (PD) based on multiwall carbon nanotubes (MWCNT) developed by chemical vapor deposition (CVD) on a Si wafer and attempt to establish a path towards commercialization of such devices, mostly having in mind potential applications related to the consumer electronics market, where low-cost and ease of use is the main requirements for the device. The first devices are constructed using an n-nype Si as substrate. On top of this a 150nm thick Si_3N_4 layer was constructed following by an Au 30nm thick layer and the MWCNTs developed by Chemical Vapor Deposition – CVD in a fixed 800 ^{0}C temperature for a variable time period (Figure 3). The first results checking the electrical and optical characterization were performed at frequencies ranging from UV (200nm) down to NIR are very promising (Figure 4). The project lately got funding by a national program for young researchers.

Publications:

- A.Filatzikioti, N.Glezos, V.Kantarelou, A. Kyriakis, G.Pilatos, G.Romanos, T.Speliotis, D.J.Stathopoulou, "Carbon nanotube Schottky type photodetectors for UV applications" Solid-State Electronics,151,(2019),27-35, https://doi.org/10.1016/j.sse.2018.10.018

Conferences:

- ATTRACT 2016 Meeting, Barcelona, Spain, https://indico.cern.ch/event/470460/contributions/1990013/attachments/1302032/1944185/CNT_Sensor_Talk_Final.pdf

Partners:

- Institute of Nanoscience and Nanotechnology (INN), NCSR "DEMOKRITOS", 15310 Agia Paraskevi, Greece

3) Low-Cost Radiation detectors

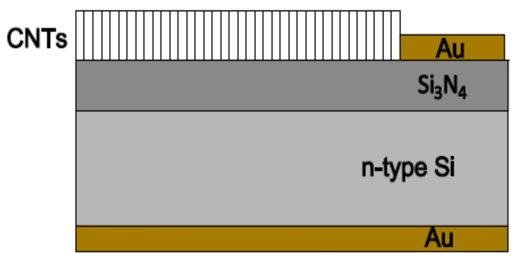

Figure 3: *Layout of the CNT photo sensor.*

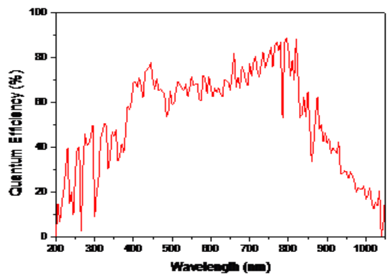

Figure 4: *Quantum efficiency of the CNT photo sensor ranging from UV (200nm) down to NIR*

The development of low cost radiation detectors that can be used as a plug-in device in cellular phones and embedded in the framework of Internet Of Things (IoT) is an ongoing project. These devices use low cost solid state radiation sensors and low-cost electronics and could be possibly used as personal dosimeters in the near future (Figure 5).

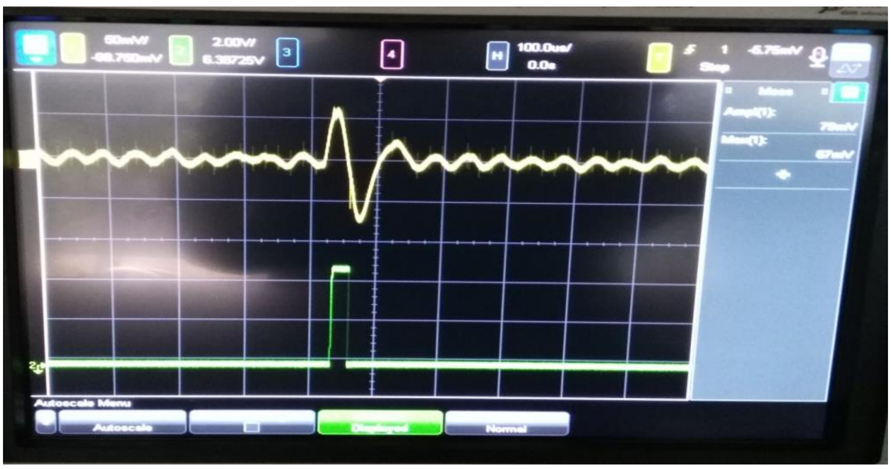

Figure 5: *Analogue Response and Discriminator Output of the low-cost radiation detector from a ^{137}Cs source irradiation.*

4) Online Optical Probes for Quality Control and Safety Assessment of Olive and Other Edible Oils

The chemical methods which are traditionally used to measure the quality parameters of olive oil and classify it as extra virgin, virgin or lampante olive oil, as well as to evaluate its nutritional and functional characteristics, are time consuming, environmentally non-friendly, expensive and often require highly qualified staff. Moreover, the oil industry requires real time chemical information of olive oil in order to control the processing parameters during production to ensure a high quality for the olive oil product.

In order to overcome the disadvantages and limitations of the previous methods, optical techniques are emerging as a more convenient technical approach. Absorption spectroscopy in ultraviolet (UV) visible (VIS) and near-infrared (NIR) areas of the spectrum or combinations of them, are currently being used for facile, non-destructive, rapid, real-time and off/on-line monitoring of olive oil quality parameters. This is accomplished directly from neat oil samples utilizing multivariate chemometric tools.

A novel portable device with an accompanying software analysis tool for the assessment of olive oil quality has been developed with the collaboration of the Institute of Nuclear and Particle Physics -NCSR Demokritos and the Chemistry Department of National and Kapodistrian University of Athens in Greece. The device has the advantages of (a) portability (b) low cost (c) no sample preparation (b) the ability to monitor the optical spectra fingerprint of olive oils during the various stages of the production process and during storage. The device in the current stage of development uses UV-Vis spectroscopy to predict the K indexes -K232, K272, ΔK- and peroxide values of oil, therefore it can easily classify oil as extra virgin, virgin or lampante. The device is using a D2 light source with emission spectrum 250-400 nm, a holographic concave grating with 430 grooves/mm and a 1024pixel CMOS array sensor. Spectra are comparable with a Schimadzu® UV-3600 UV-Vis-NIR spectrophotometer which has been used for calibration reasons. Neat, filtered olive oil samples without any other treatment are placed in a flow cell 1 mm light path by using a peristaltic pump. The recorded spectra and analytical data are processed with multivariate chemometric tools generating PLS models for prediction of each parameter. More information in: http://probeoil.inp.demokritos.gr/PROBEOIL/.

The new device is capable of measuring neat olive oil samples, without the use of solvents, rendering the method suitable for on-line utilization in olive oil mill during production and storage conditions. The results can be monitored in real time or transferred into a central data base for analysis.

Further development of the device can include the extension of its capabilities in the near infrared (NIR) regions so as to collect optical spectra fingerprints and chemical information concerning other olive oil quality parameters such as acidity, moisture and functional compounds such as phenolic compounds, fatty acids, tocopherols, chlorophylls and carotenoids. Our device can be evolved into a portable versatile industrial product and its utilization can be extended not only to monitor other parameters of olive oil but also to other edible or non-edible oils, food products available as aqueous solutions (wine, milk, tomato juice e.t.c.). Solid food products can also be analyzed by NIR reflection spectroscopy and the extension of our device towards this direction is also desirable.

Aristometro – A portable device to detect the concentration of oleocanthal and oleacein in olive oil.

Over two thousand years ago, Hippocrates and Dioscorides referred to early harvest olive oil as medicinal. Modern science has identified the polyphenols, or more accurately phenolic compounds, that are health protective and continue to research the effectiveness of these phenols for the prevention and treatment of many of today's chronic illnesses, including heart attack and stroke, high blood pressure, rheumatoid arthritis, obesity, Alzheimer's, Parkinson's, Type II Diabetes and cancer. It is well known that most illness is the result of inflammation and it is the phenolic compound Oleocanthal that is known for its anti-inflammatory properties. Oleocein is a known antioxidant. These compounds are only found in olive oil. In 2012, the EU made a health claim labelling regulation 432-2012. In it is stated that olive oils with polyphenols over 250 mg/kg can put a health claim on the label as it reduces LDL oxidation. In the same year, Dr. Prokopios Magiatis and Dr. Eleni Melliou of the University of Athens discovered a method to accurately measure individual phenolic compounds in olive oil using NMR (Nuclear Magnetic Resonance). The following year they invented a test kit to measure the combined phenolic compounds Oleocanthal and Oleacein. In the heart of this test kit stands the Aristometro, a specially designed and built by INPP, portable spectrometer to detect the concentration of oleocanthal and oleacein in olive oil.

The developed spectrometer succeeded a remarkable performance and gained the first prize of competition "INNOVATION & ENTREPRENEURSHIP 2018" in olive oil sector.

Education & Outreach activities

Education activities correspond to a significant part of the activities of the Institute of Nuclear and Particle Physics. These include activities addressed to university level students, as well as high school and even primary school aged children.
Due to the loss of the funding for graduate study scholarships for NCSR Demokritos in general, the number of doctoral students has oscillated strongly coupled to the availability or lack of additional funding through funded research programs.

The main educational activities can be summarized below:

- Supervision and guidance of Graduate students towards a PhD degree in Particle, Astroparticle and Nuclear Physics. INPP collaborates with the National Technical University of Athens (NTUA) in a program which leads to a Master's degree in Physics (obtained by NTUA). The researchers of INPP and professors of NTUA jointly teach graduate classes in this program.

- In the period 2015-2017, the following Ph.D. degrees have been awarded:

  - Çapak Mustafa, "Special Solutions of the Bohr Hamiltonian with the Woods-Saxon potential", Dr. D. Bonatsos, 2015
  - Paneta Valentina, "Study of differential cross sections suitable for EBS and NRA", Dr. A. Lagoyannis, 2015
  - Vasilike Kantarelou, "Development evaluation and application of micro-X ray fluorescence spectrometry on cultural heritage", Dr. A. Karydas, 2015
  - Drakopoulou Evaggelia, "Muon and Neutrino energy reconstruction in KM3NeT", Dr. C. Markou, and Dr. E. Tzamariudaki, 2016
  - Martinou Antriana, "Nucleon-Nucleon Interaction in Stable and Unstable Nuclei", Dr. D. Bonatsos, 2017
  - Topsis Iason, "Search for New Physics in final states with photons and missing transverse energy, with the CMS experiment at CERN", Dr. A. Kyriakis, 2017

- Researchers of INPP have supervised and guided students in the completion of their Master thesis, Diploma thesis, as well as practical training for undergraduate students through agreements with Universities and Technical Universities in Greece. Students are trained by participating to the research projects of the Institute in order to acquire a training certificate (about 1 -3 months training) or a diploma thesis (about 6 months training).

- In 2016 a new annual educational activity "Cadet Researchers" was initiated. It targets talented lyceum students who are invited to spend 1 full week in INPP, performing experiments in the laboratories of INPP under the supervision of INPP researchers. Each year, 6-8 students are selected, through a physics competition in April. In 2016, the first year of this activity, 5 schools participated with about 60 students. In the second year, 2017, after obtaining the support of the Ministry of Education, 19 schools participated with more than 110 students.

- Every year the Physics Masterclass in collaboration with CERN is organized, in which high school students attend a one-day introduction to particle physics, followed by an interactive online session with other participating schools from all over Europe.

- INPP scientists have been members of the organizing committees and have participated as lecturers in summer schools for University and graduate students and young scientists.

- INPP researchers are involved in developing and delivering popularized science lectures to public or school audiences. Also presentations and lectures and guiding tours are being given to schools visiting Demokritos and its facilities (among them INPP and the Tandem accelerator) with a few hundred visitors each year.

- INPP researchers have been heavily involved in the "Greek Researchers night" activities, traditionally held at the end of September each year.