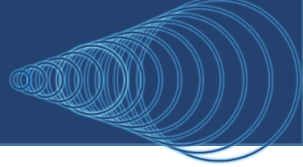


Αστροσωματιδιακή Φυσική στο ΙΠΣΦ

Χρήστος Μάρκου
Κατερίνα Τζαμαριουδάκη
Ευαγγελία Δρακοπούλου

05/05/2023



Η γέννηση ενός νέου και συναρπαστικού πεδίου έρευνας

Στο πρόσφατο παρελθόν:

- Ανίχνευση νετρίνο από τον ήλιο
 - αποδεικνύοντας ότι η ενέργεια του Ήλιου παρέχεται από σύντηξη
- Ανίχνευση νετρίνο από supernova (1987)
 - 20 (Kamionade: 12) supernova νετρίνο – επιβεβαίωση της βασικής θεωρητικής εικόνας του θανάτου ενός άστρου

Nobel Prize 2002



Αρχικές πειραματικές μετρήσεις: αριθμός των νετρίνο που φτάνουν στη Γη από τον Ήλιο: $\sim 1/3$ του αναμενόμενου από τη θεωρία “**solar neutrino puzzle**”

Ανιχνευτές Super-Kamiokande & SNO: τα νετρίνο από τον Ήλιο δε χάνονται καθώς ταξιδεύουν προς τη Γη αλλά αλλάζουν ταυτότητα

Nobel Prize 2015

Η αλλαγή της ταυτότητας των νετρίνο μπορεί να γίνει μόνο αν τα νετρίνο έχουν μάζα

Το καθιερωμένο πρότυπο δεν αποτελεί πλήρη θεωρία των θεμελιωδών συστατικών του Σύμπαντος

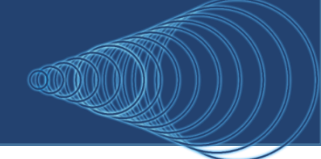
“For the greatest benefit to mankind”
Alfred Nobel
2015 NOBEL PRIZE IN PHYSICS
Takaaki Kajita
Arthur B. McDonald

2015 Nobel Prize in Physics
The Nobel Prize in Physics 2015 was awarded jointly to Takaaki Kajita and Arthur B. McDonald “for the discovery of neutrino oscillations, which shows that neutrinos have mass”.

LIVE WEBCAST ON NOW
Announcement
Nobel Prize in Physics

Watch the 2015 Nobel Prize Announcements Live

Greetings to the 2015 Nobel Laureates
“CONGRATULATIONS for this achievement which should truly engage many more of us to work towards suc...”
/Maria Vincent
+ Post your greetings!



νετρίνο

- δεν έχουν ηλεκτρικό φορτίο
- έχουν αμελητέα μάζα
- πρακτικά δεν απορροφώνται
- προϊόντα πυρηνικών διεργασιών

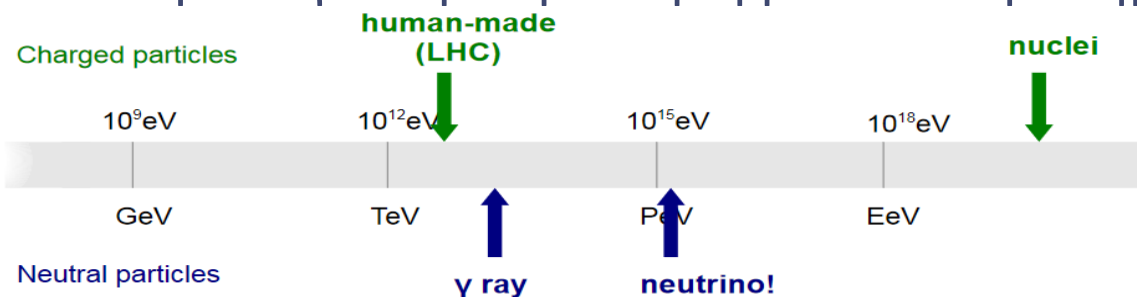
❖ ανίχνευση νετρίνο: μια πρόκληση

- Ανίχνευση 2000 νετρίνο από τον Ήλιο σε μια περίοδο 30 ετών!
- Ανίχνευση 12 νετρίνο από τα 10^{16} νετρίνο που πέρασαν μέσα από τον ανιχνευτή Kamiokande!
- ❖ Μια σύγχρονη μαζική εκπομπή νετρίνο παρατηρήθηκε **2-3 ώρες πριν** την άφιξη του φωτός από το SN 1987A στη Γη.

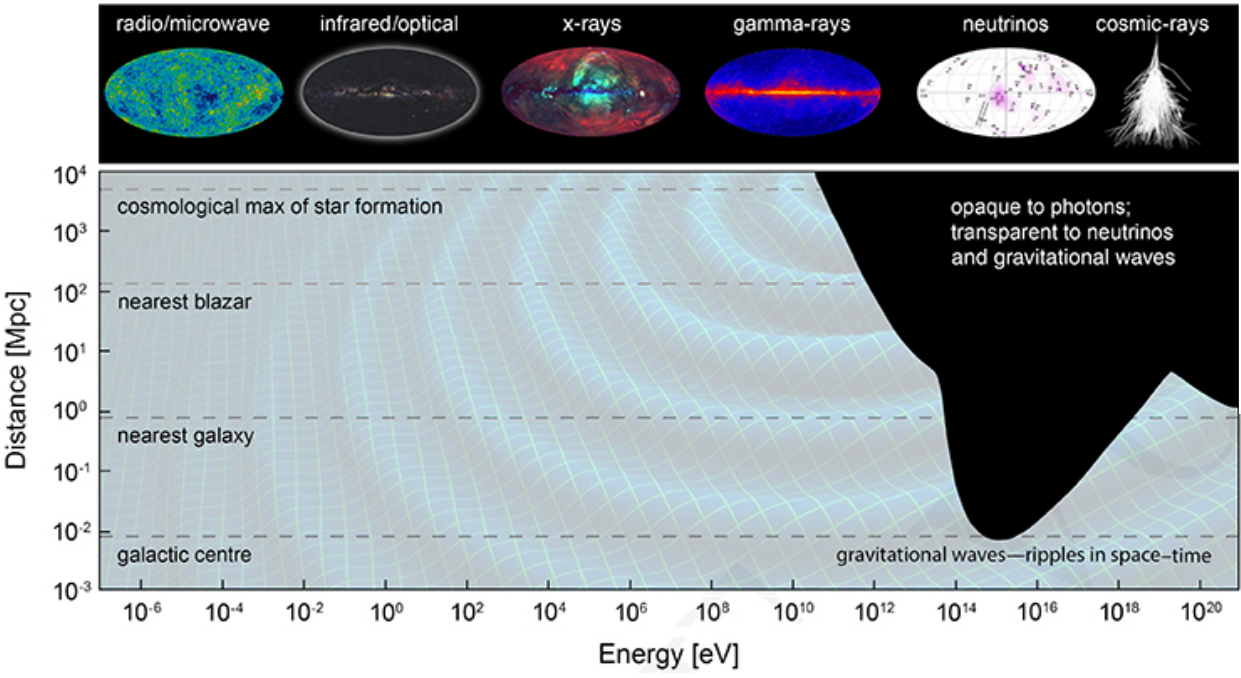
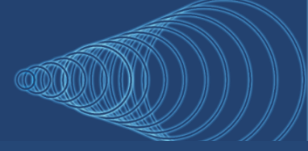
- Ανίχνευση νετρίνο από τον ήλιο ✓
- Ανίχνευση νετρίνο από supernova (1987) ✓

• Ανίχνευση νετρίνο από γαλαξιακές και εξω-γαλαξιακές πηγές

- νετρίνο ως φορέας πληροφορίας για τα φαινόμενα υψηλής ενέργειας στο Σύμπαν (neutrino: the twitter of the Universe)
- νετρίνο – δέσμη σωματιδίων από τον ουρανό για τη διερεύνηση βασικών ερωτημάτων της Σωματιδιακής Φυσικής



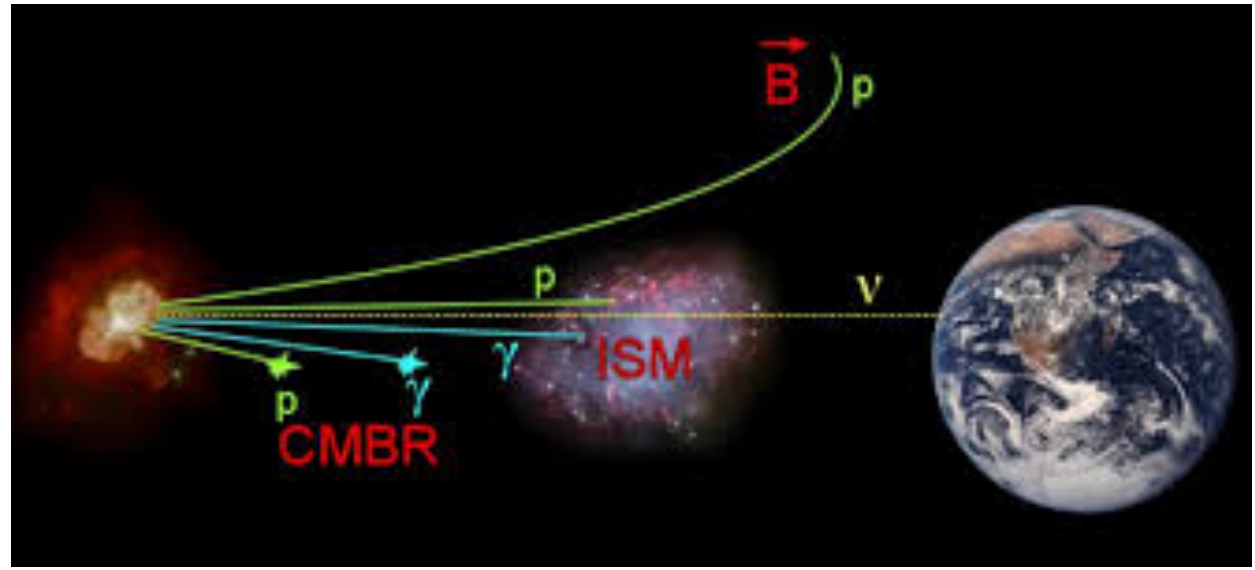
Φαινόμενα υψηλής ενέργειας στο Σύμπαν: φορείς πληροφορίας



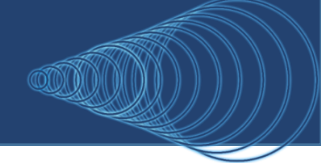
- φωτόνια
- κοσμικές ακτίνες
- νεutrίνο
- βαρυτικά κύματα

$\nu \rightarrow$ Αλληλεπιδρούν μέσω της ασθενούς αλληλεπίδρασης

- Ταξιδεύουν σε ευθύγραμμες τροχιές!
- Πρακτικά, δεν απορροφώνται από την μεσοαστρική ύλη!
- Μπορούν να αποκαλύψουν πληροφορίες σχετικά με τις διεργασίες στις αστροφυσικές πηγές που δεν είναι «προσβάσιμες» μέσω φωτονίων ή κοσμικών ακτίνων

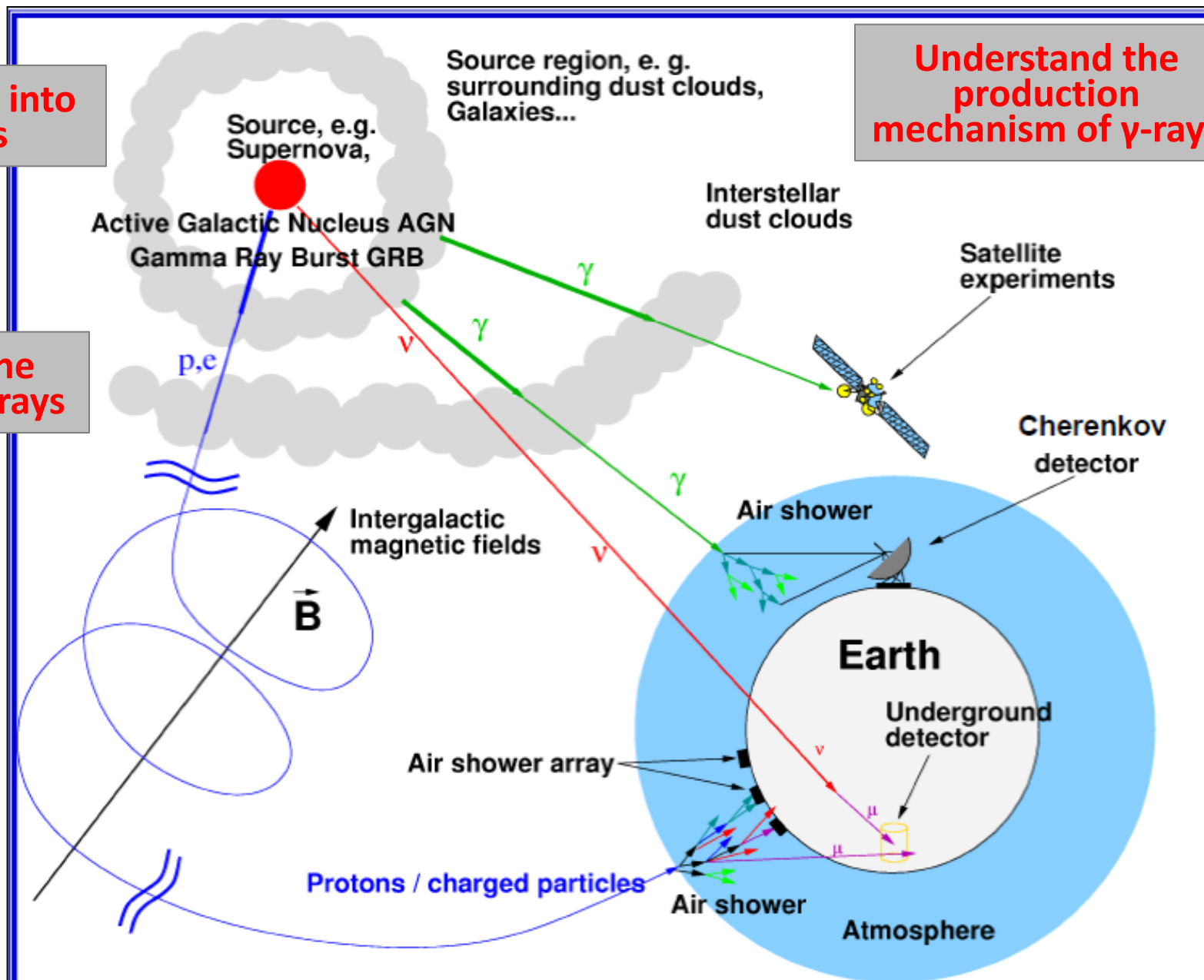


Αστρονομία Νετρίνων: το όνειρο!



see deeper into sources

learn what is the origin of cosmic rays



Understand the production mechanism of γ -rays

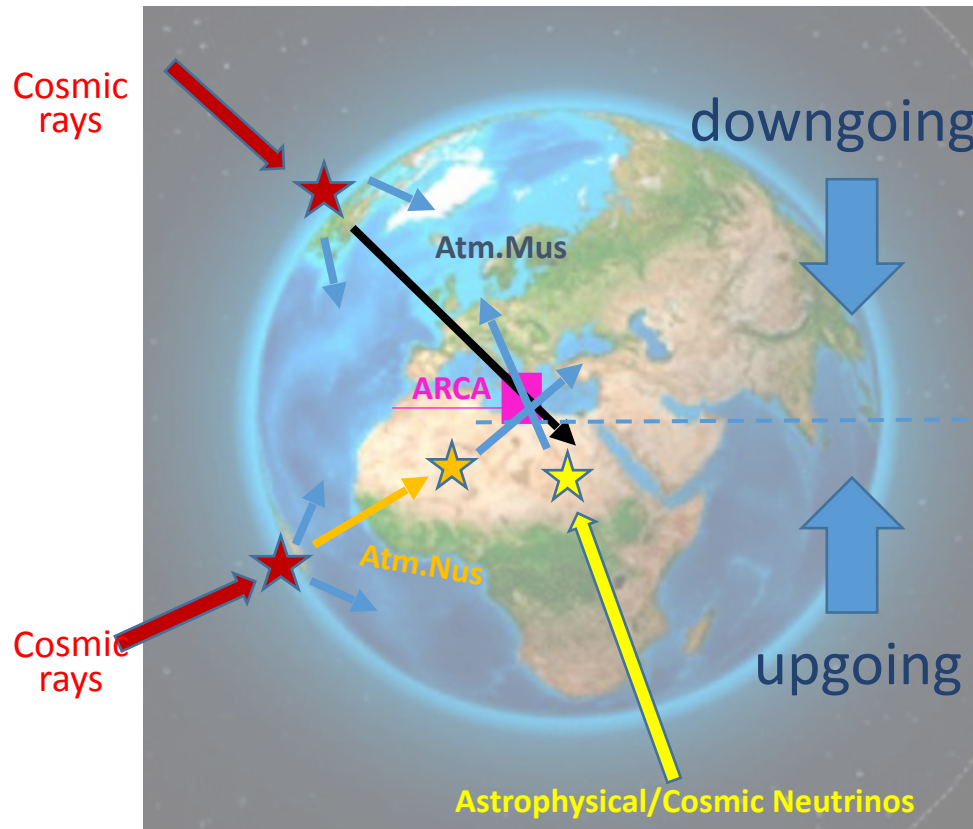
Multi-messenger astronomy

Αστρονομία Νετρίνων: η πραγματικότητα!

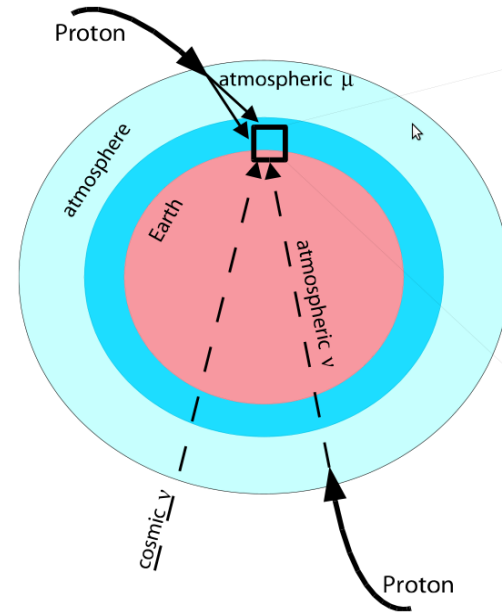
~50.000.000 atm.μ / year

Πρόκληση!

~300.000 atm.ν / year



~600 ν of astrophysical origin / year



- Σήμα: νεutrίνο αστροφυσικής προέλευσης
- Υπόβαθρο: νεutrίνο και μόνια που παράγονται στην ατμόσφαιρα.

• Numbers refer to ARCA with 2 building blocks of 115 DUs each

• $10^{-4} \left(\frac{E^{-2}}{GeV} \right) e^{(-\frac{E}{3PeV})} GeV^{-1} m^{-2} s^{-1} sr^{-1}$ Applied astrophysical flux: 1.2.

- Σήμα: νεutrino αστροφυσικής προέλευσης
- Υπόβαθρο: νεutrino που παράγονται στην ατμόσφαιρα.
μίονια που παράγονται στην ατμόσφαιρα.

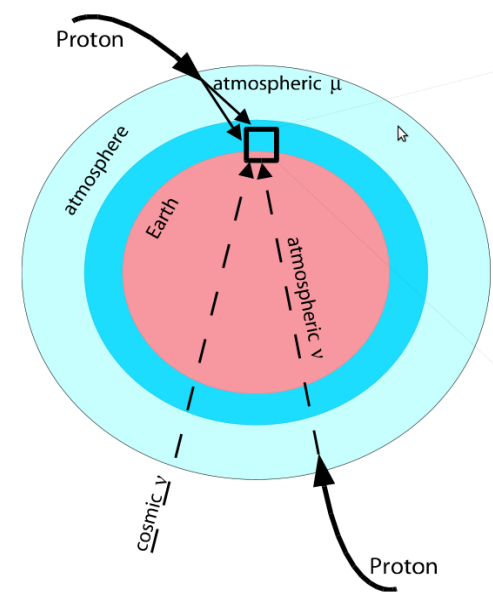
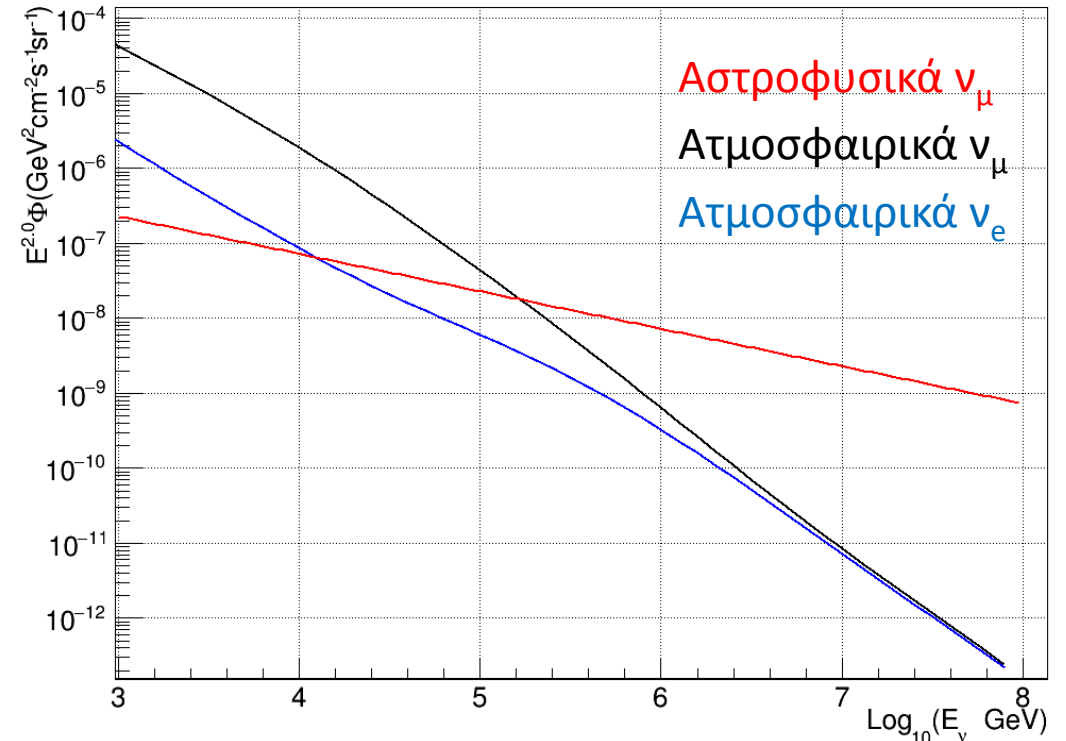
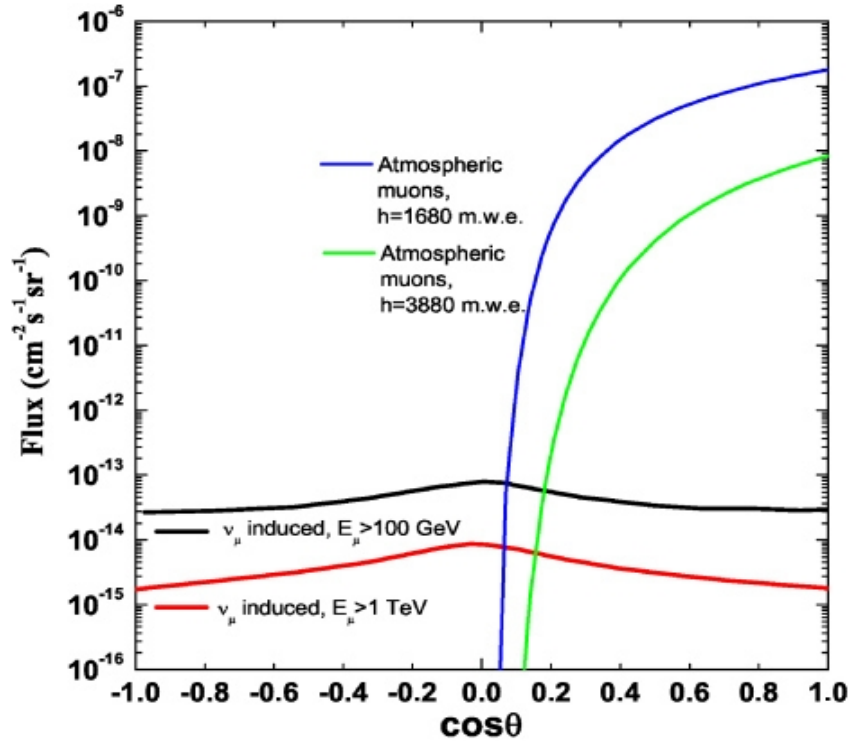
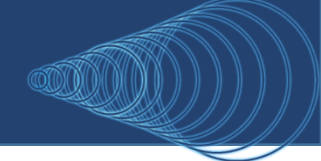
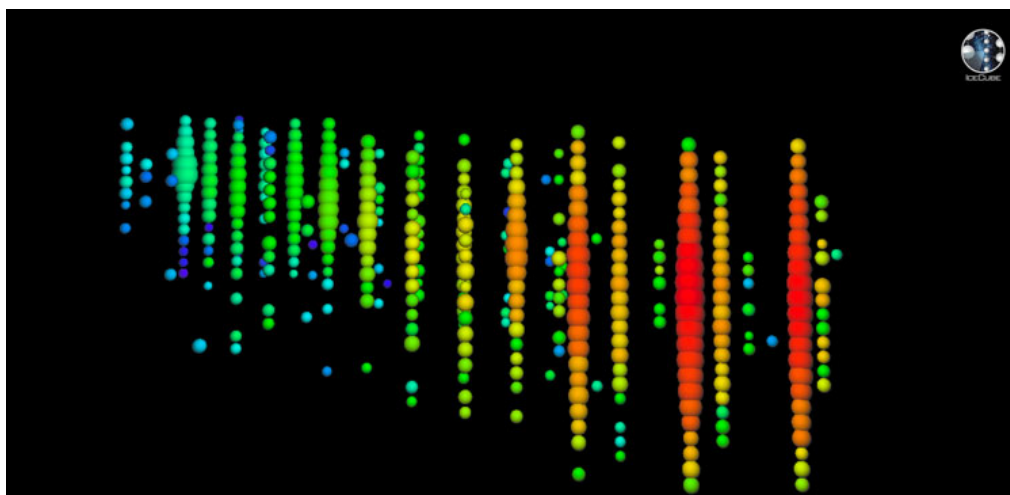


Figure 12 from High-energy neutrino astronomy: detection methods and first achievements B Baret and V Van Elewyck 2011 Rep. Prog. Phys. 74 046902





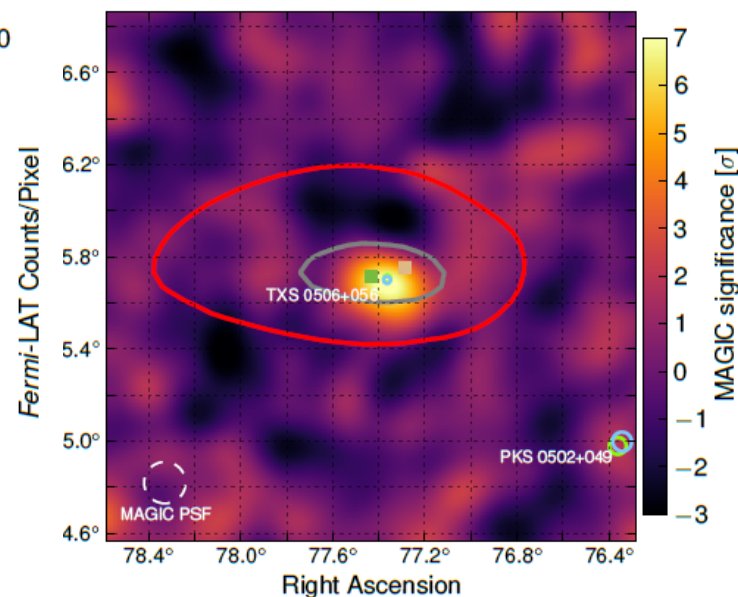
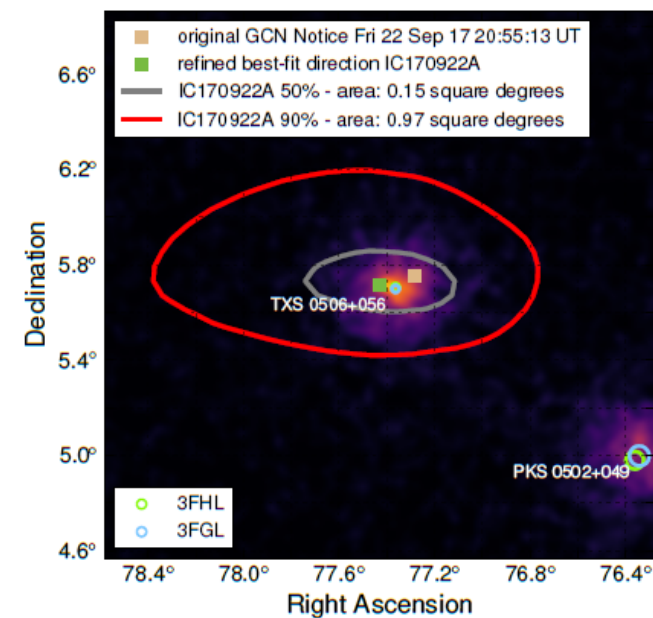
IceCube-1709
22A



→ IceCube Alert

Για την εξερεύνηση των φαινομένων υψηλής ενέργειας στο σύμπαν: συνδυασμός πληροφορίας

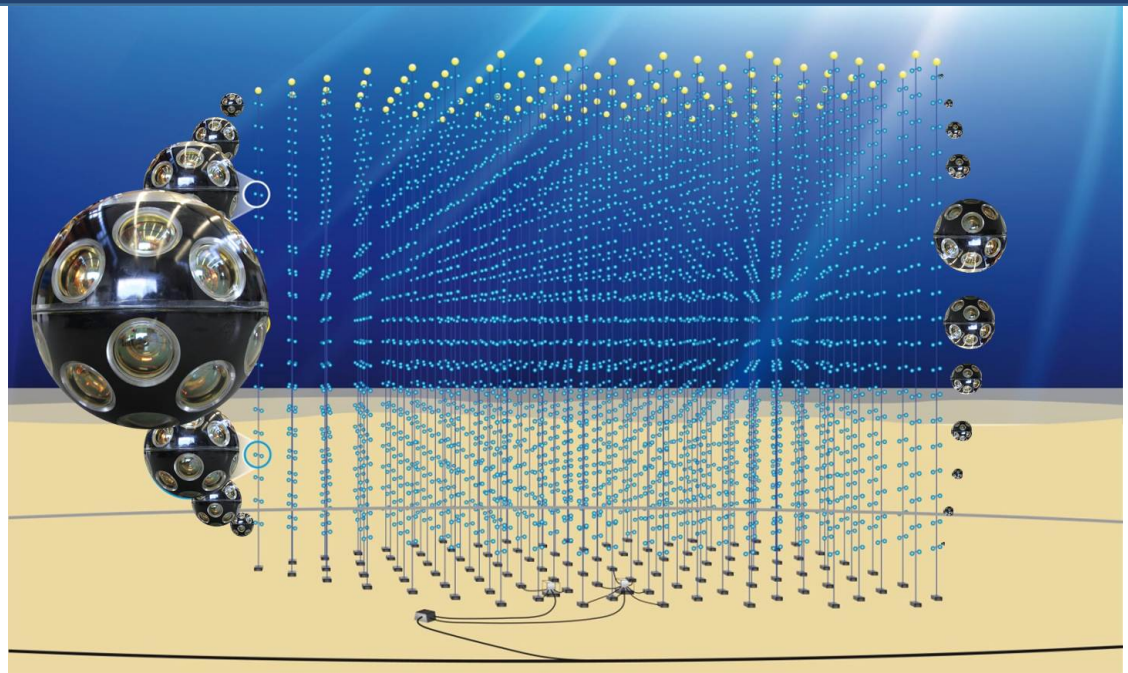
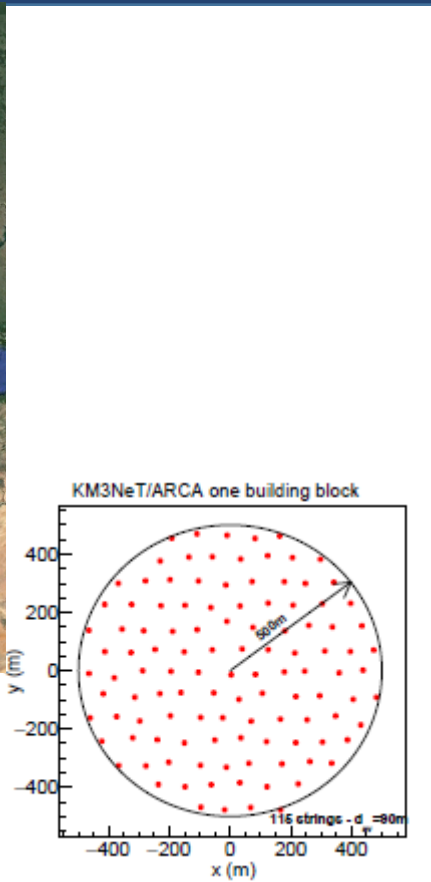
- φωτόνια
- νετρίνο
- βαρυτικά κύματα
- κοσμικές ακτίνες



22/09/2017: νετρίνο ενέργειας ~ 300 TeV ανιχνεύθηκε από το τηλεσκόπιο νετρίνο IceCube.

Σύμπτωση 3σ με τις παρατηρήσεις του Flaring Blazar TXS 0506+056 από τα Fermi-LAT και MAGIC

KM3NeT: Ανιχνευτές νετρίνο νέας γενιάς στη Μεσόγειο



ORCA

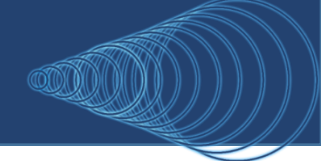
2x

ARCA

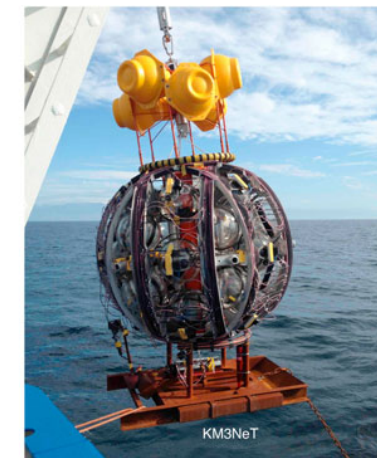
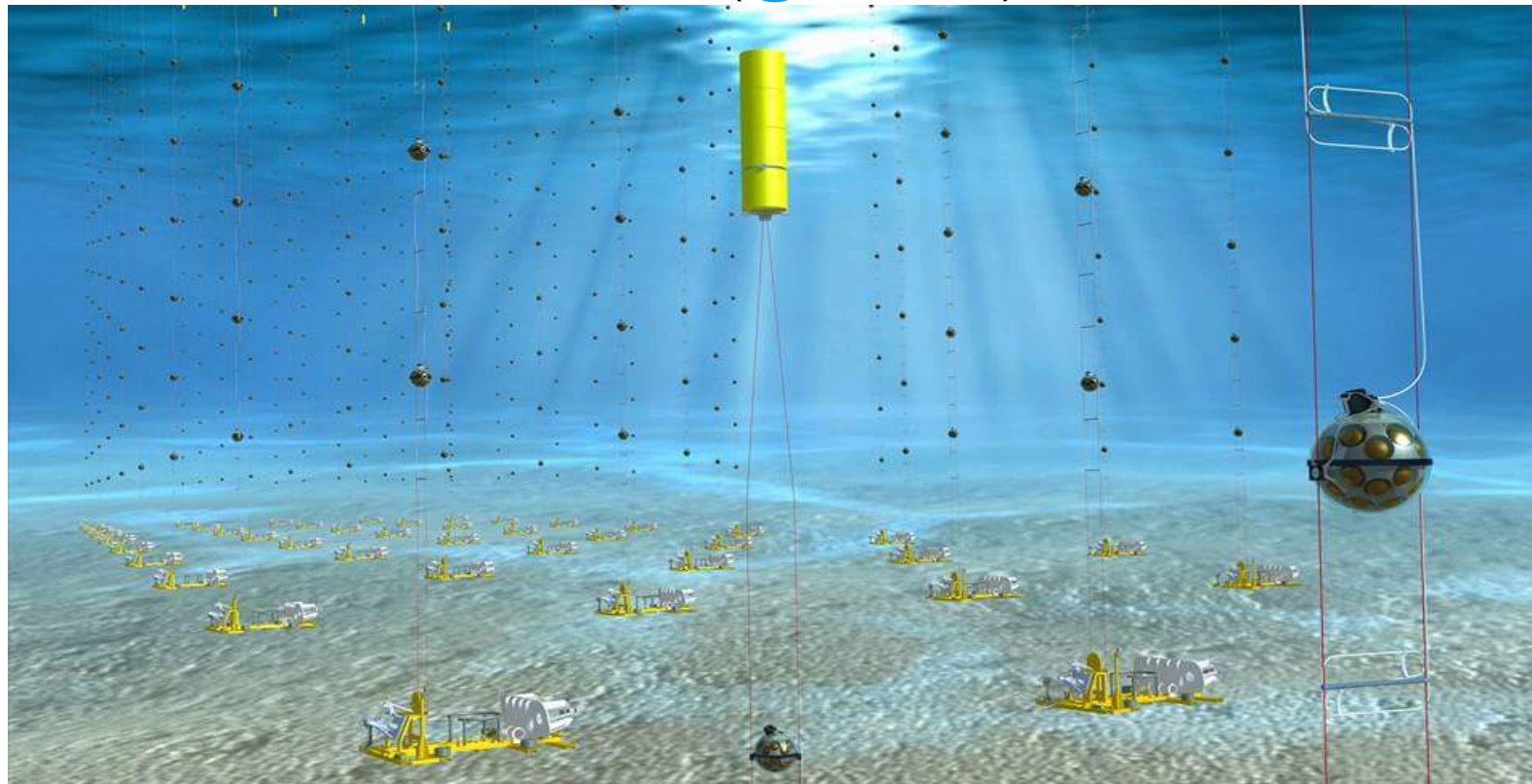
Ανιχνευτής νετρίνο:
Σωματιδιακή φυσική
Ταλαντώσεις νετρίνο
Ιεραρχία μαζών

Τηλεσκόπιο νετρίνο:
Ανίχνευση νετρίνο αστροφυσικής
προέλευσης





KM3NeT in the Mediterranean (km3net)



ORCA: Oscillation Research with Cosmics In the Abyss
 Μελέτη χαμηλής ενέργειας ατμοσφαιρικών νετρίνο

ARCA: Astroparticle Research with Cosmics In the Abyss
 Ανίχνευση νετρίνο αστροφυσικής προέλευσης

Expecting lots of new data!!



April 2021
 6 ARCA
 6 ORCA

Spring 2022
 7 ARCA

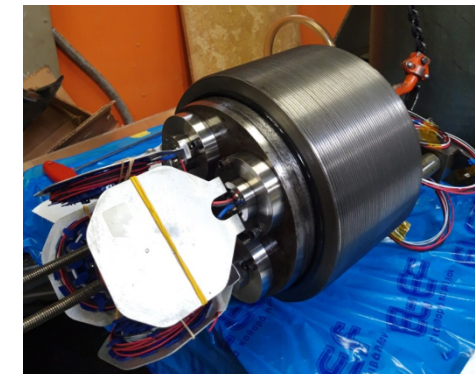
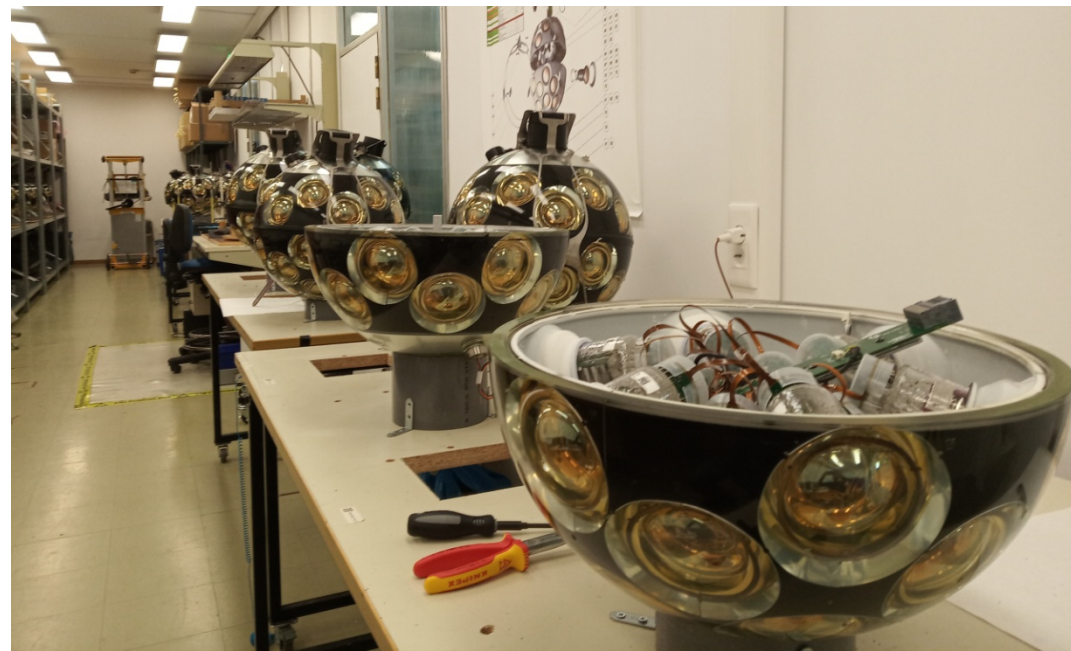
Summer 2022
 +12 ARCA
 +4 ORCA

Fall 2022
 +4 ARCA
 +4 ORCA

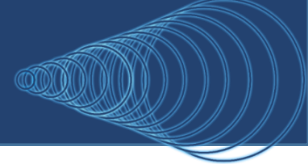
NOW
 ARCA21
 ORCA18

APP group: 3 ερευνητές, τεχνικό προσωπικό, 1 φυσικός, 3 Ph.D. Students, 1 MSc student

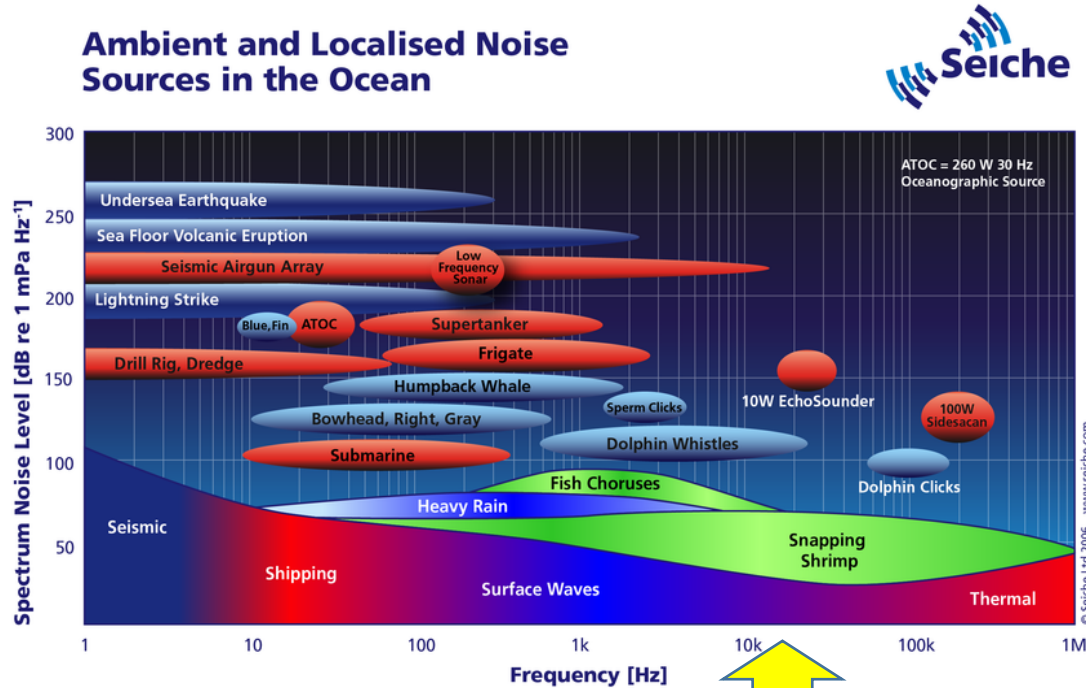
Undergraduate students - interns



- Κατασκευή και έλεγχος οπτικών στοιχείων του πειράματος KM3NeT
- Συμμετοχή στη βαθμονόμηση και τον έλεγχο συνιστωσών των DOMs
- Έλεγχος της αντοχής των συνιστωσών των DOMs στην πίεση της βαθιάς θάλασσας



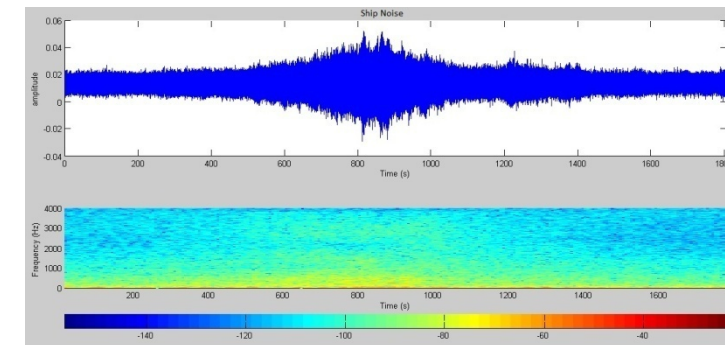
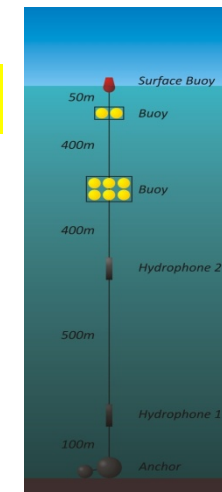
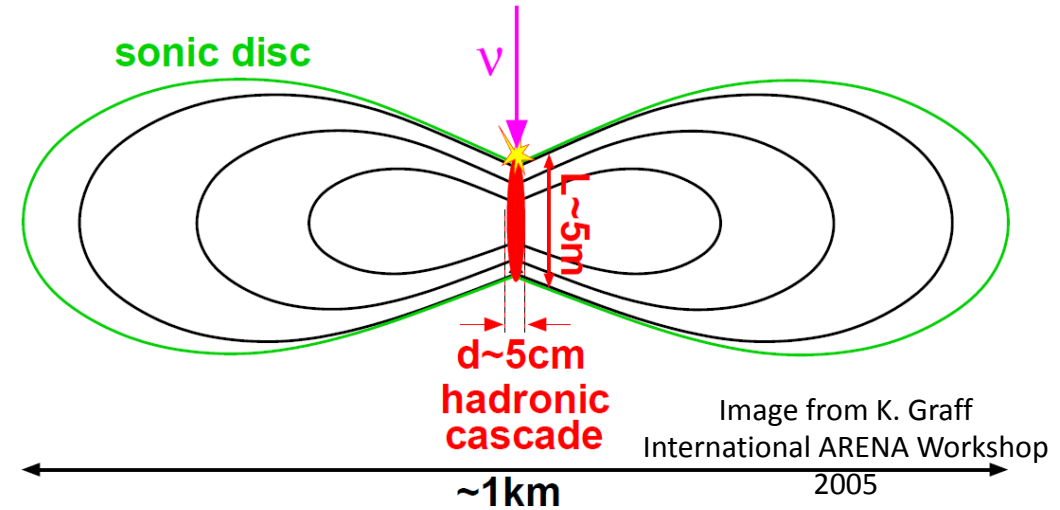
➤ Ίσως ο πλέον υποσχόμενος τρόπος ανίχνευσης νετρίνο εξαιρετικά υψηλών ενεργειών (κόστος – δυνατότητες)



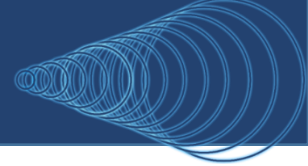
αναμενόμενο σήμα από αλληλεπιδράσεις νετρίνο

Ανάλυση ακουστικού σήματος και κατηγοριοποίηση:

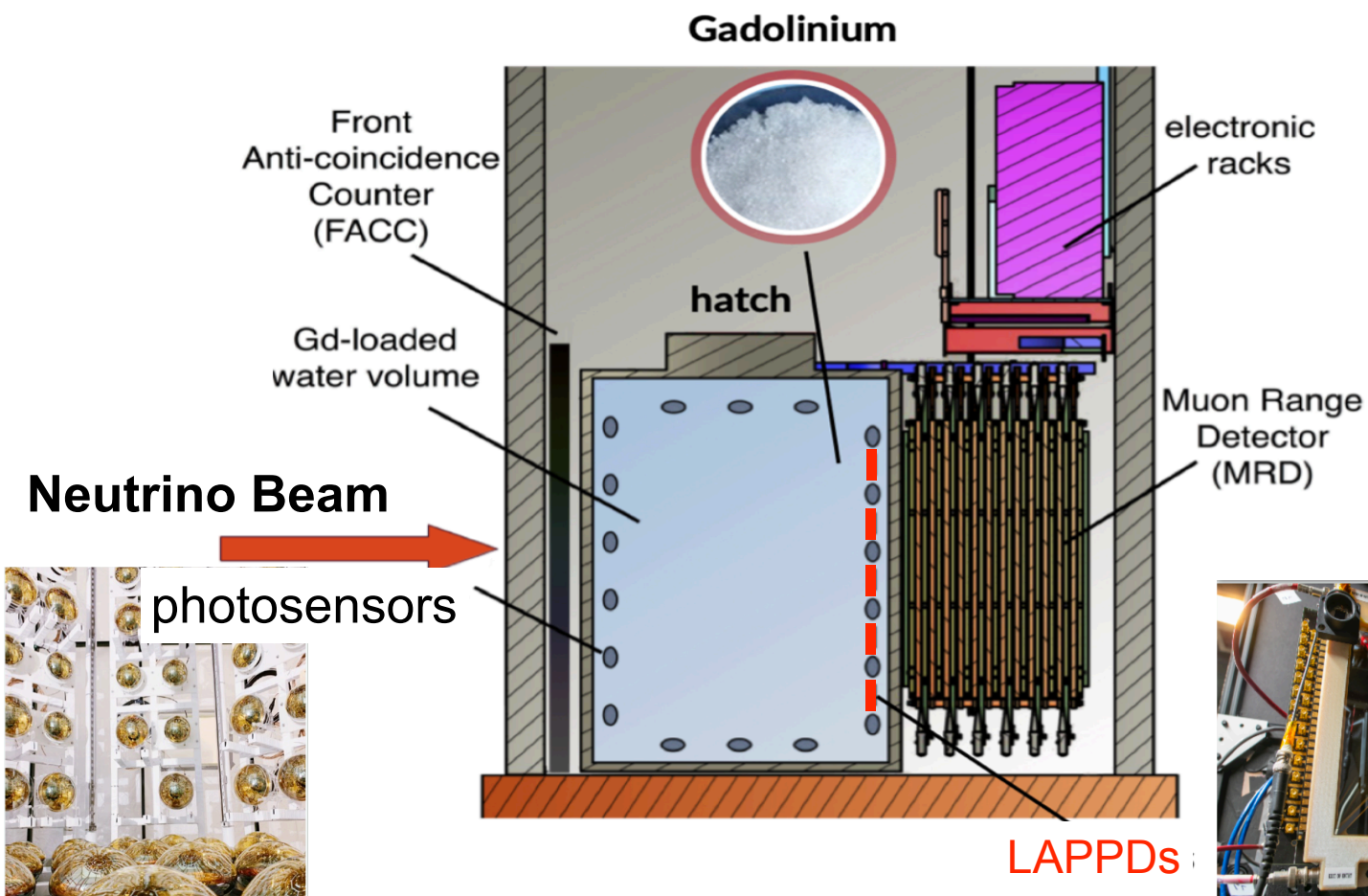
- Αναμενόμενο σήμα από αλληλεπίδραση νετρίνο
- Δεδομένα από την καταγραφή των υδροφώνων (Καλαμάτα 2018) και των ακουστικών αισθητήρων του KM3NeT για την προσομοίωση του υποβάθρου.



The ANNIE experiment

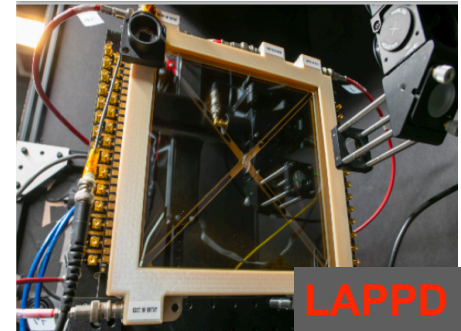


- **Accelerator Neutrino Neutron Interaction Experiment (ANNIE)**: ένας Gd-doped water Cherenkov ανιχνευτής 26 τόνων στη δέσμη νετρίνων του Fermilab ($E \sim 600$ MeV).
- We joined ANNIE in September 2021.

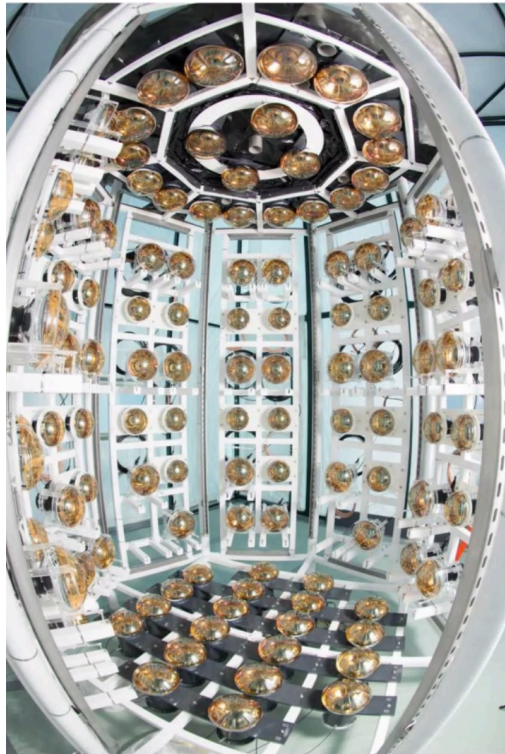
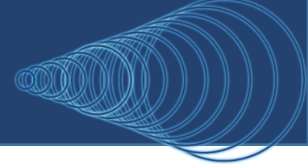


Detection Medium: Now: Gadolinium-loaded water, mid 2022: Water-based Liquid Scintillator.

- Το ANNIE είναι το πρώτο πείραμα που χρησιμοποιεί φωτοανιχνευτές ταχείας απόκρισης (~ 60 psec time resolution) **Large Area Picosecond PhotoDetectors (LAPPDs)** για ανακατασκευή γεγονότων νετρίνων.



ANNIE is seeing neutrinos with the first LAPPD deployed in the water tank.



2016

2018

2023

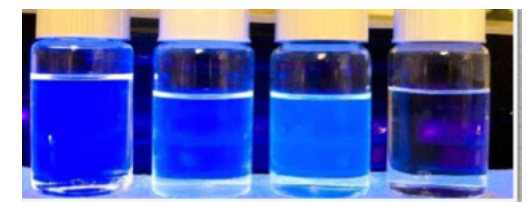
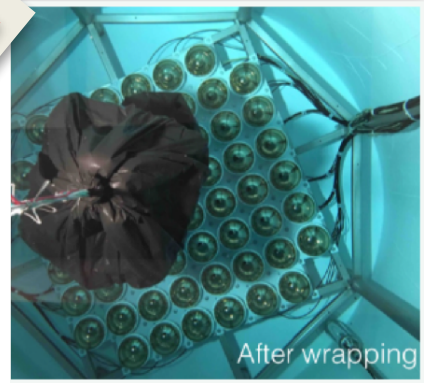
Past:
ANNIE – Phase I

Present:
ANNIE – Phase II

Future:
ANNIE – Phase III

Completed

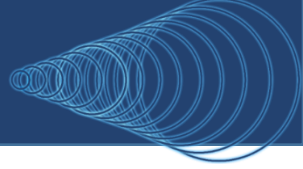
NOW



- Μέτρηση του υποβάθρου του ανιχνευτή
- Επιτυχής λειτουργία του ανιχνευτή

- Μέτρηση της πολλαπλότητας νετρονίων από CCQE γεγονότα
- Πρώτη πόντιση και λειτουργία των LAPPDs

- Περισσότερα LAPPDs: βελτιωμένη ανακατασκευή
- Water-based Liquid Scintillator (WbLS)



2020-2022

Neutrinos from ARCA, ORCA and ANNIE

A. Sinopoulou PhD student

D. Stavropoulos PhD student

Detection of atmospheric neutrinos with the first detection units of KM3NeT-ARCA

A.Sinopoulou^{1,2*}, R.Congioma¹ and E.Zamariudaki¹ on behalf of the KM3NeT Collaboration

1. Institute of Nuclear and Particle Physics, N.C.S.R. Demokritos, Athens, Greece
2. National Technical University of Athens, Athens, Greece
3. INFN - Laboratori Nazionali del Sud, Catania, Italy

Abstract: KM3NeT [1] is a research infrastructure that will host a set of underwater neutrino detectors which are currently being constructed in the Mediterranean Sea. ARCA and ORCA [2] will employ ~2000 m² of photomultiplier tubes (PMTs) to detect muon neutrinos (ν_μ) generated in the Earth's atmosphere for study. Fundamental neutrino physics, ARCA will be used for the search of high energy neutrinos (HEN) from distant astrophysical sources such as blazars, stars and colliding jets. When completed, ARCA will consist of 3 building blocks of 125 Detection Units (DUs) covering an instrumental volume of ~1 km³. A DU hosts 18 Digital Optical Modules (DOMs), each housing up to 31 PMTs providing a detection area of ~120 m². A DU has a 200 m height and a 20 m diameter. The ARCA detector is currently under construction in the Mediterranean Sea. The first detection units (DUs) were deployed in October 2020. This paper reports on the first detection of atmospheric neutrinos with the first deployed DUs of the ARCA detector.

The zenith angle distribution is shown in Fig. 2 for all reconstructed events (left) and after background subtraction (right). The distribution of the zenith angle for atmospheric neutrinos is compared with the distribution of the zenith angle for muon neutrinos. The distribution of the zenith angle for atmospheric neutrinos is shown in Fig. 3 for all reconstructed events (left) and after background subtraction (right). The distribution of the zenith angle for atmospheric neutrinos is compared with the distribution of the zenith angle for muon neutrinos. The distribution of the zenith angle for atmospheric neutrinos is shown in Fig. 4 for all reconstructed events (left) and after background subtraction (right). The distribution of the zenith angle for atmospheric neutrinos is compared with the distribution of the zenith angle for muon neutrinos.

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References

[1] https://www.km3net.org
[2] J. Hofstadter et al. (KM3NeT Collaboration), PoS (ICRC2019) 910
[3] B. Strandberg, S. Hallmann (KM3NeT Collaboration), PoS (ICRC2019) 1019

All-sky and galactic plane diffuse cosmic neutrino flux analysis with KM3NeT/ARCA data

A.Sinopoulou^{1,2*}, F.Filippini¹, E.Drakopoulou¹ and E.Zamariudaki¹ on behalf of the KM3NeT Collaboration

1. Institute of Nuclear and Particle Physics, N.C.S.R. Demokritos, Athens, Greece
2. National Technical University of Athens, Athens, Greece
3. INFN - University of Bologna, Italy

Abstract: KM3NeT [1] is a research infrastructure that will host a set of underwater neutrino detectors which are currently being constructed in the Mediterranean Sea. ARCA and ORCA [2] will employ ~2000 m² of photomultiplier tubes (PMTs) to detect muon neutrinos (ν_μ) generated in the Earth's atmosphere for study. Fundamental neutrino physics, ARCA will be used for the search of high energy neutrinos (HEN) from distant astrophysical sources such as blazars, stars and colliding jets. When completed, ARCA will consist of 3 building blocks of 125 Detection Units (DUs) covering an instrumental volume of ~1 km³. A DU hosts 18 Digital Optical Modules (DOMs), each housing up to 31 PMTs providing a detection area of ~120 m². A DU has a 200 m height and a 20 m diameter. The ARCA detector is currently under construction in the Mediterranean Sea. The first detection units (DUs) were deployed in October 2020. This paper reports on the first detection of atmospheric neutrinos with the first deployed DUs of the ARCA detector.

The detection of a diffuse flux of cosmic neutrinos will provide information on the production mechanisms, composition and acceleration of Cosmic Rays. Signal from these sources are difficult to detect individually. The limited instrumental volume of ARCA leads to poorly reconstructed neutrino energies that decrease the observed rate [3]. Cosmic neutrinos accounting the astronomical flux [4], are completely obscured with a $\sim 10^3$ orders of magnitude lower than atmospheric neutrinos.

Suppression of the atmospheric neutrino flux by means of a galactic plane selection, which is an extension of [5], is a detection complementary reaction from the first data demonstrating the capability of the ARCA detector.

Abstract: KM3NeT [1] is a research infrastructure that will host a set of underwater neutrino detectors which are currently being constructed in the Mediterranean Sea. ARCA and ORCA [2] will employ ~2000 m² of photomultiplier tubes (PMTs) to detect muon neutrinos (ν_μ) generated in the Earth's atmosphere for study. Fundamental neutrino physics, ARCA will be used for the search of high energy neutrinos (HEN) from distant astrophysical sources such as blazars, stars and colliding jets. When completed, ARCA will consist of 3 building blocks of 125 Detection Units (DUs) covering an instrumental volume of ~1 km³. A DU hosts 18 Digital Optical Modules (DOMs), each housing up to 31 PMTs providing a detection area of ~120 m². A DU has a 200 m height and a 20 m diameter. The ARCA detector is currently under construction in the Mediterranean Sea. The first detection units (DUs) were deployed in October 2020. This paper reports on the first detection of atmospheric neutrinos with the first deployed DUs of the ARCA detector.

References

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[3] B. Strandberg, S. Hallmann (KM3NeT Collaboration), PoS (ICRC2019) 1019

Observation of the atmospheric neutrino flux with the first detection units of KM3NeT/ORCA

Luigi Antonio Fusco¹, Jannik Hofstadter², Dimitris Stavropoulos³ on behalf of the KM3NeT Collaboration

¹ CPPM, Marseille ² ECAP, Erlangen ³ NCSR Demokritos, Athens
*luigi.fusco@cppm.in2p3.fr

Abstract: KM3NeT [1] is the next generation large volume neutrino detector in the Mediterranean Sea. The KM3NeT/ORCA apparatus, currently being constructed off the coasts of Southern France, will be devoted to the study of neutrino physics using atmospheric neutrino oscillations.

The KM3NeT Detector

6 Detection Units (DUs), vertical strings hosting multi-PMT Digital Optical Modules (DOMs) are currently taking data. The final detector configuration will be composed of 115 DUs, over a volume of ~8 Mton

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Data sample and Neutrino selection

4.5 months of high-quality KM3NeT/ORCA data acquired with 4 active DUs between July 2019 and January 2020 have been considered. Neutrino-induced track-like events, reconstructed as upward-going, allow for a 99% pure neutrino sample with an event rate of 2-3 y/day.

A refined event selection [2] has been used to study neutrino oscillations. KM3NeT/ORCA data favours the hypothesis of oscillations at a significance level of roughly 2σ by measuring the zenith-dependent differences in track-like event rates.

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References

[1] https://www.km3net.org
[2] J. Hofstadter et al. (KM3NeT Collaboration), PoS (ICRC2019) 910
[3] B. Strandberg, S. Hallmann (KM3NeT Collaboration), PoS (ICRC2019) 1019

Reconstruction Techniques in ANNIE

Evangelia Drakopoulou on behalf of the ANNIE Collaboration

Abstract: The Accelerator Neutrino Neutron Interaction Experiment (ANNIE) is a 26-ton Gd-doped water Cherenkov detector installed in the Booster Neutron Beam (BNB) at Fermilab. The experiment has two complementary goals: (1) make a unique measurement of the neutron yield from neutron-nucleus interactions to improve the systematic uncertainties in calibration experiments and (2) demonstrate the power of our fast timing, position-sensitive photodetectors by making the first deployment of Large Area Proton Recoil Detectors (LAPDs) in a physics experiment. To realize these goals, the ANNIE collaboration has developed several reconstruction techniques using the arrival time and position of photons in the detector photomultipliers (PMT) and LAPDs. A maximum-likelihood fit is used to reconstruct the neutrino interaction vertex and direction. Machine and Deep Learning techniques are used for the energy reconstruction, particle identification and the ring counting. We present recent progress on ANNIE reconstruction techniques.

ANNIE - Phase II:

Two main goals:
- Measure the neutron multiplicity from neutron-nucleus interactions in water
- Demonstrate the use of LAPDs for event reconstruction.

Status:
- Physics data taking (Phase II) since summer 2020.
- First LAPD deployed.

LAPDs are MCP-based fast-timing photodetectors

- Size: Large-area: 20 cm x 20 cm
- Photoelectron timing: ~100 ps for SPE
- Quantum efficiency: >20%
- Position resolution: sub-mm

M. Breda et al. "Operating LAPDs in ANNIE" (Poster) V. Anagnostopoulos "Fast timing LAPPDs in neutrino physics with the ANNIE Collaboration"

Machine and Deep Learning Techniques

Energy Reconstruction

- The neutrino track length is reconstructed using Deep Learning Neural Networks.
- The reconstructed track length is passed to a Boosted Decision Tree with other variables to reconstruct the mean (neutrino) energy resolution of the ANNIE detector at the 68th percentile is 10% (14%).

Ring Counting and Particle Identification

- For the selection of a Charged Current $1\mu\text{s}$ sample in ANNIE two Convolutional Neural Networks (CNN) have been developed.
- The first CNN selects events with a single particle track (single-ring) over multiple tracks (multi-ring) and the second CNN discriminates between muons and electrons (Particle Identification).

Vertex Reconstruction

- Algorithms based on a maximum-likelihood fit to reconstruct the neutrino interaction vertex and direction.
- Muons that are produced within a fiducial volume and stop inside the MRD are selected.
- Vertex Radial Displacement Δr

Conclusions

- ANNIE is taking data since summer 2020.
- The first LAPD has been deployed. Four more LAPDs will be deployed during the next months.
- ANNIE reconstruction techniques show good performance.
- The addition of 5 LAPDs significantly improves the vertex reconstruction in ANNIE.

More than 30 Collaborators from 5 Countries

presented in the XXIX International Conference on Neutrino Physics and Astrophysics 2020, NEUTRINO 2022

3 contributions accepted for ICRC2023!

Neutrino candidates with the first deployed DUs of the KM3NeT-ARCA detector

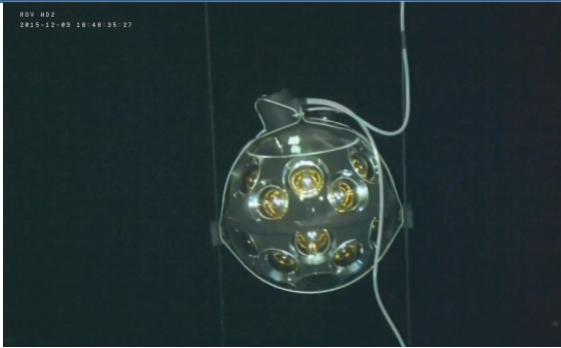
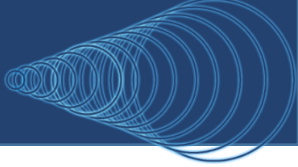
Neutrino candidates with the first deployed DUs of the KM3NeT-ARCA detector (KM3NeT.DUANA.2020.001)

Anna Sinopoulou, Ekaterini Tzamariudaki, Christos Markou
October 5, 2020

Abstract: KM3NeT.DUANA.2020.001 Atmospheric neutrinos with ARCA1 & ARCA2 A.Sinopoulou.v1

Anna Sinopoulou, Ekaterini Tzamariudaki, Christos Markou

NCSR "Demokritos", Patr. Grigoriou E' & 27 Neapoleos St., 15341, Agia Paraskevi, Greece



Expecting lots of new data!!

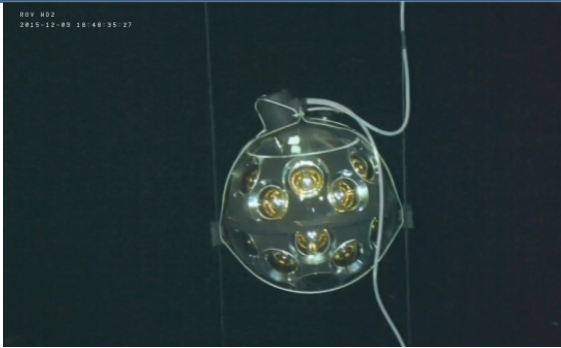
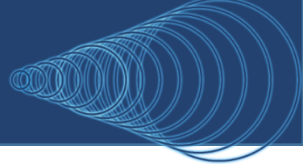
@ the APP group: a phased construction of the KM3NeT detectors

- Συμμετοχή σε ένα πείραμα κατά τη διάρκεια της κατασκευής του
- Συλλογή και ανάλυση δεδομένων (τεχνικές Machine Learning) από τους ανιχνευτές ARCA & ORCA

Πληροφορίες στο: <http://www.inp.demokritos.gr/education/>

Astroparticle Physics

- *"Measurement of the atmospheric muon flux for the current KM3NeT ARCA & ORCA configurations"*, (M.Sc. Thesis, Dr. E. Tzamariudaki)
- *"Comparison of machine learning-based track reconstruction with standard reconstruction algorithms"*, (MSc thesis, Dr. E. Drakopoulou)
- *"Studies of atmospheric muon simulations"* (M.Sc. Thesis, Diploma Thesis, Dr. E. Tzamariudaki)
- *"Development of framework and machine learning applications on GPUs"* (M.Sc. thesis, Diploma Thesis, Internship, Dr. C. Markou)
- *"Development of tools to assess the performance of machine learning algorithms used in neutrino experiments"* (M.Sc. thesis, Diploma thesis, Dr. E. Drakopoulou)
- *"Reconstruction studies for acoustic neutrino detection"* (MSc thesis, Dr. C. Markou)
- *"Development of machine learning algorithms for the ANNIE experiment"* (M.Sc. thesis, Diploma thesis, Dr. E. Drakopoulou)



Expecting lots of new data!!

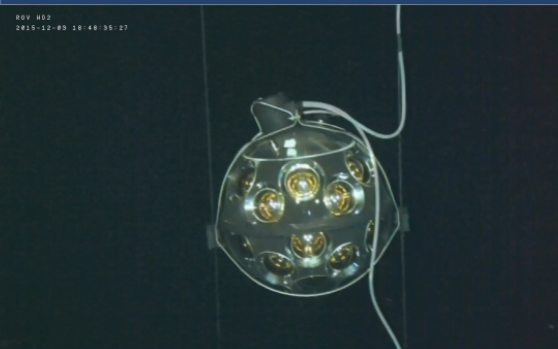
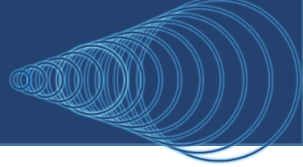
@ the APP group: a phased construction of the KM3NeT detectors

❑ **ARCA & ORCA data:** atmospheric neutrino candidates (atmospheric muon background suppression)

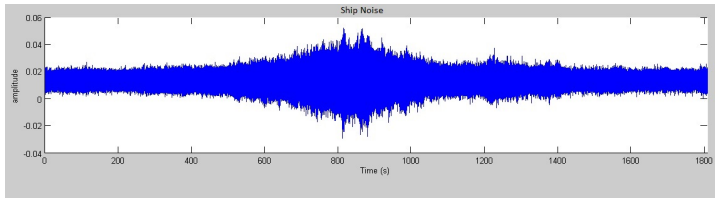
- ARCA: βελτιστοποίηση των αλγορίθμων για την επιλογή καλά ανακατασκευασμένων γεγονότων
- ORCA: βελτιστοποίηση των αλγορίθμων για την επιλογή: γεγονότων που αλληλεπιδρούν μέσα στον ανιχνευτή, μιονίων που προέρχονται από νετρίνα που έρχονται διαμέσου της Γης
- σύγκριση της ροής με τη ροή που αναμένεται από τα διαφορετικά μοντέλα που περιγράφουν τους κοσμικούς καταιονισμούς

❑ **Simulation studies:** αναγνώριση της τοπολογίας των γεγονότων (track – shower differentiation) χρησιμοποιώντας μεθόδους μηχανικής μάθησης στοχεύοντας στη βελτιστοποίηση της ικανότητας ανακάλυψης διάχυτης ροής νετρίνο αστροφυσικής προέλευσης

❑ **Multi-messenger astronomy:** Για την εξερεύνηση των φαινομένων υψηλής ενέργειας στο σύμπαν απαιτείται συνδυασμός της πληροφορίας από φωτόνια, κοσμικές ακτίνες, βαρυτικά κύματα και νετρίνο.



&&



Acoustic neutrino detection: expecting new activities!!!

- ❑ Ανάπτυξη μεθόδων για την αναγνώριση, το χαρακτηρισμό και την κατηγοριοποίηση ηχητικών σημάτων χρησιμοποιώντας τεχνικές μηχανικής μάθησης
- ❑ Ανάλυση των γεγονότων που καταγράφονται από τους ακουστικούς αισθητήρες του KM3NeT με στόχο τη δημιουργία ενός trigger ειδικά για acoustic neutrino detection
- ❑ Ανάπτυξη πρότυπων ανιχνευτικών διατάξεων ακουστικής ανίχνευσης σε συνεργασία με NL, DE, IT, FR.



Η ανίχνευση νετρίνο υψηλής ενέργειας σε σύμπτωση με τις παρατηρήσεις του Flaring Blazar TXS 0506+056 από τα Fermi-LAT και MAGIC σηματοδοτεί την έναρξη της εποχής της κατανόησης του Σύμπαντος χρησιμοποιώντας πολλαπλούς φορείς πληροφορίας από τις αστροφυσικές πηγές

Μπορείτε να συμμετέχετε σε αυτή τη συναρπαστική εποχή!!

Γνωρίστε το APP group:

- Συμμετοχή σε ένα πείραμα κατά τη διάρκεια της κατασκευής του
- Ανάλυση δεδομένων από τους ανιχνευτές ARCA, ORCA & ANNIE
- Μελέτη της ροής νετρίνο χρησιμοποιώντας εξελιγμένα εργαλεία ανάλυσης δεδομένων
- Εκτεταμένη χρήση μεθόδων μηχανικής μάθησης (Machine Learning)
- Ανίχνευση νετρίνο από αστροφυσικές πηγές!
- **Lots of fun!!**

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Python
Techniques
nning
on deadline: 28 June 2022