Θεόδωρος ΓΕΡΑΛΗΣ
Ερευνητής Α'
ΙΠΣΦ, ΕΚΕΦΕ Δημόκριτος
28/1/2020

Η ΟΜΑΔΑ ΤΟΥ ΔΗΜΟΚΡΙΤΟΥ ΣΤΟ ATLAS/LHC ΕΡΓΑΣΤΗΡΙΟ ΟΡΓΑΝΟΛΟΓΙΑΣ ΑΝΙΧΝΕΥΤΩΝ «ΕΛΕΑ»

Στοιχεία επικοινωνίας:
Email: geral@inp.demokritos.gr
Τηλ. 210 6503536

Postgraduate Students Workshop
28 January 2020, NCSR "DEMOKRITOS", Athens, Greece

The ATLAS Group – 2018/2019

- **October 2017**: NCSR Demokritos **full member** of **ATLAS**

Researchers

Georgios Fanourakis
Theodoros Geralis
Georgios Stavropoulos
Vasiliki Kouskoura (new member)

Doctoral Students

Maria-Myrto Prapa
Olga Zormpa

Master Thesis

Kostas Damanakis

Diploma

Vasilis Blanas

Technician (Electronics)

Yiannis Kiskiras

Practical work (2018)

Stamatis Tzanos (NTUA)
Vasilis Blanas (NTUA)
Stathis Logothetis (NTUA)
Eva Eleftheriou (Univ. Patras)
Despina Stasinou (Univ. Patras)
Athanasia Papaioannou (Univ. Patras)

ATLAS EXPERIMENT

ΕΡΕΥΝΗΤΙΚΕΣ ΔΡΑΣΤΗΡΙΟΤΗΤΕΣ

1) **ΤΟ ΠΕΙΡΑΜΑ ATLAS ΣΤΟ LHC**

ΑΝΑΒΑΘΜΙΣΗ ΤΟΥ ATLAS (2020 – 2021): Μυονικό Σύστημα Ανιχνευτών
Ανιχνευτές Μικρομέγας και sTGC (NSW: New Small Wheel)

ΑΝΑΚΑΤΑΣΚΕΥΗ ΤΡΟΧΙΩΝ ΜΙΟΝΙΩΝ - ΑΝΑΛΥΣΗ ΦΥΣΙΚΗΣ
... Φυσική με το νέο ανιχνευτή

2) **ΕΡΕΥΝΑ ΚΑΙ ΑΝΑΠΤΥΞΗ ΣΕ ΑΝΙΧΝΕΥΤΙΚΑ ΣΥΣΤΗΜΑΤΑ**
α) Μικρομέγας τεχνολογίας Microbulk πραγματικού x-y
β) Αντιστατικοί Μικρομέγας για υψηλές ροές σωματιδίων
δ) Τεχνολογία Μικρομέγας με χρήση γραφενίου

Ο ΜΕΓΑΛΟΣ ΑΔΡΟΝΙΚΟΣ ΕΠΙΤΑΧΥΝΤΗΣ – LARGE HADRON COLLIDER (LHC)

Επιταχυντής LHC: Συγκρούσεις p − p, Pb − Pb, p − Pb

Ecm(p-p) = 13 TeV

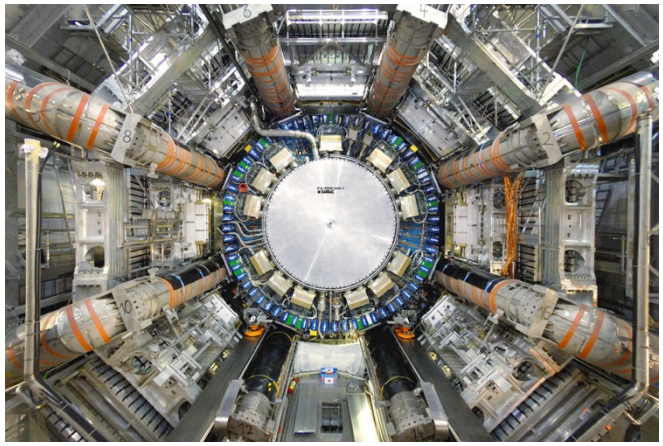
Στόχοι: Μελέτη του Καθιερωμένου Προτύπου − Ενδελεχής μελέτη του Higgs

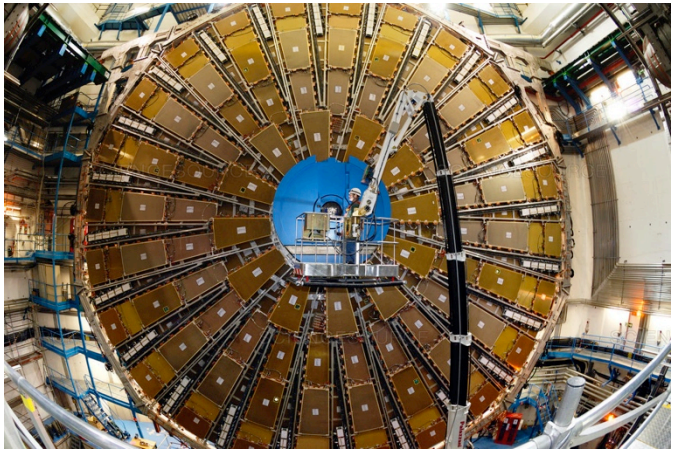
Έρευνα για Υπερσυμμετρία (Πρόβλημα ιεραρχίας − Μεγάλη ενοποίηση − Σκοτεινή Ύλη)

Έρευνα για Σκοτεινή Ύλη

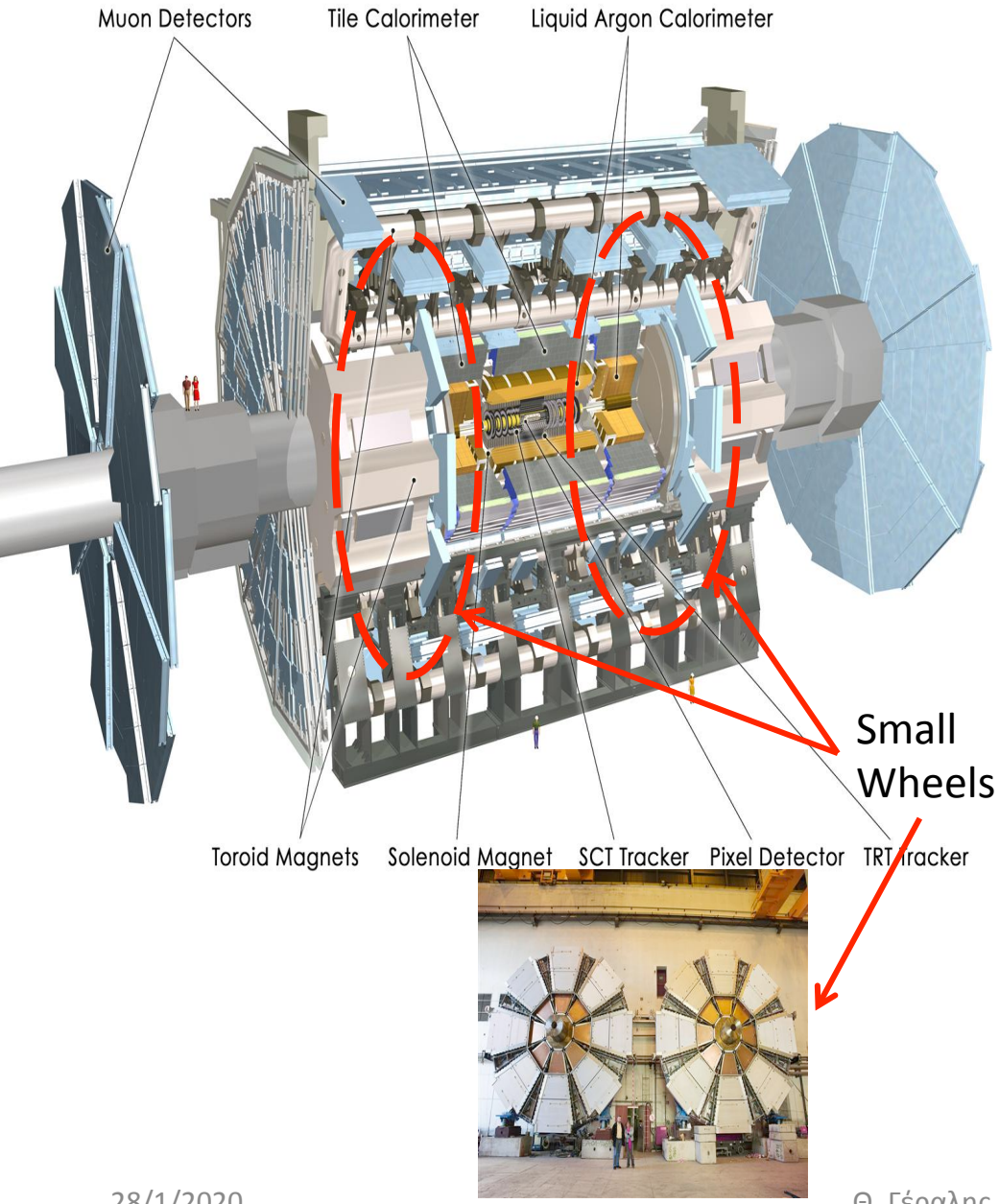
Επιπλέον διαστάσεις

Μη προβλεπόμενα φαινόμενα





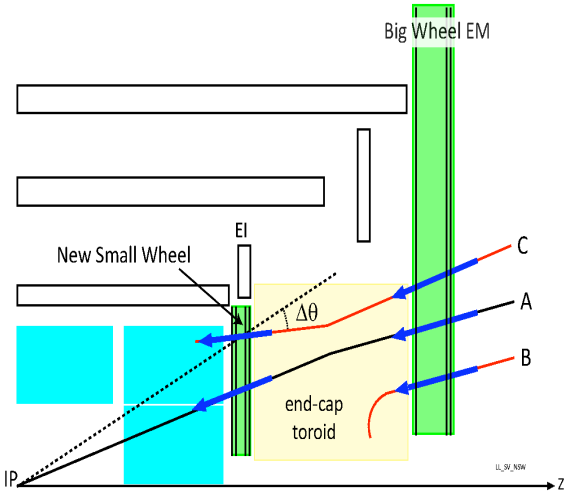
Το πείραμα ΑΤΛΑΣ και η Αναβάθμισή του

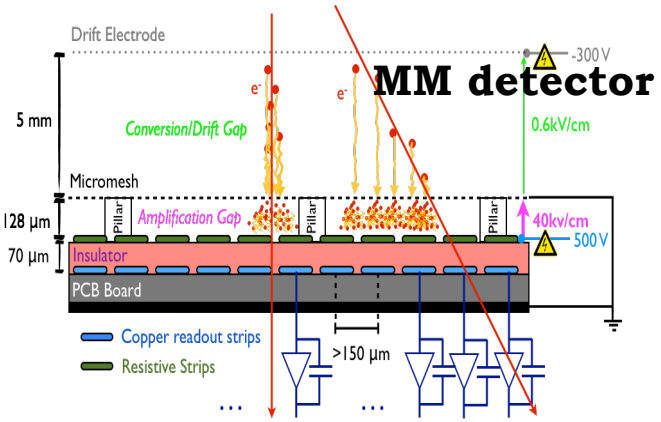


- ATLAS – Πείραμα Γενικού στόχου (δες προηγούμενη σελίδα)
- Μιονικό φασματόμετρο: Small wheels (between end-cap calorimeter and end-cap toroid)
- Διάμετρος 10 m
- Αποτελείται από ανιχνευτές:
  - Cathode Strip Chambers (CSC)
  - Thin Gap Chambers (TGC)
  - Monitor Drift Tube (MDT)

NEW SMALL WHEELS

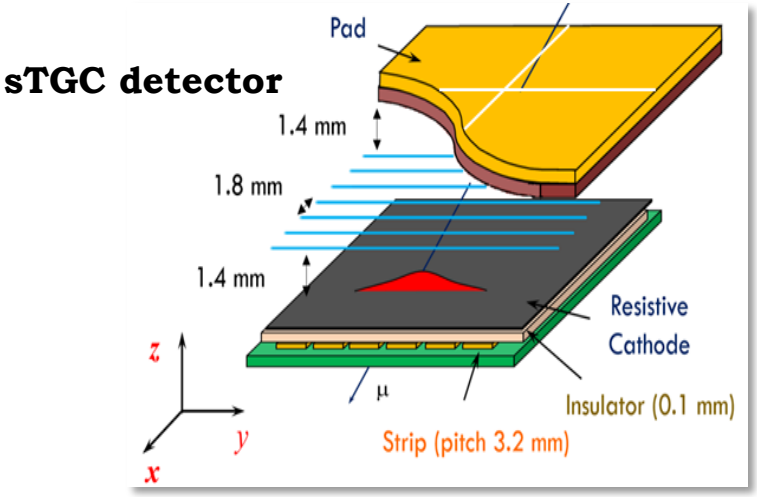
Operation principle MMs and sTGC (NSW Technologies)





New Small Wheels (NSW)

- Work at high rates 20kHz/cm^2
- Will provide online high angle resolution (σ_θ~1mrad) IP pointing segments
- Spatial resolution at 100 μm
- Significant reduction of fake triggers



Micromegas – 2,097,152 channels

MM strips for tracking, first hit for trigger

-Strip pitch: 450 μm, Readout Strips: 300 μm

-Data rates: Up to 8 Gbps/plane

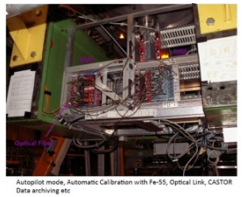
sTGC – 331,744 channels

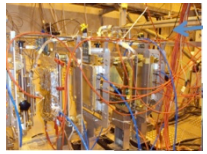
- sTGC wires/strips for tracking, strips/pads for trigger
  - -Wires: 50 μm, pitch 1.8 mm
  - -Strips: pitch 3.2 mm
  - -Data rates: up to 1.77 Gbps/plane

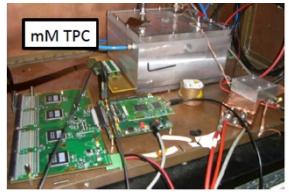
ELEA past Activities

- **Manufacturing and testing the CAST Micromegas detectors (2001 – 2005)**
- **Built VME DAQ for Micromegas (LabView and C++ parallel threads) – CAST, SPS test beams (2003, 2012)**
- **Design and built the Global Trigger Processor Emulator (GTPe) for CMS (2005 – 2010) – 10 complete systems**
- **Build the first RD51 telescope with Micromegas, for the SPS test beam (2010)**
- **Build Micromegas TPC for fission studies FIDIAS project (2012)**

- **Participate in the MAMMA collaboration for The ATLAS New Small Wheel upgrade (2010)**







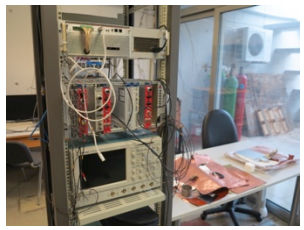
ELEA aim at:

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

INFRASTRUCTURE

- **THREE FULLY EQUIPPED TEST BENCHES FOR STUDYING MPGDs**
  - **Electronics Rack, Gas distribution, Workstation, Osciloscope**

- **GAS MIXER and distribution of premixed gases**



- **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 PS, LV PS, Pulse generators, NIM/TTL/NIM conv, etc), MCAs (2), Preamps**
  - **Faraday cage**

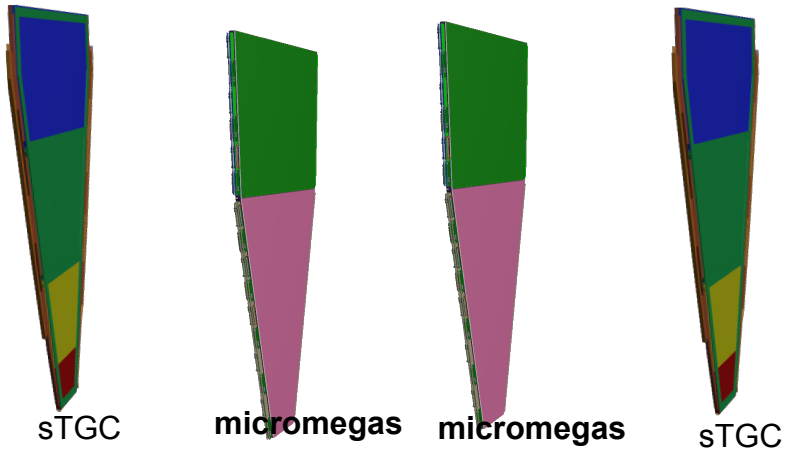
- **DESIGN PACKAGES**
  - **Electronics design (Europractice packages)**
  - **Finite Element Analysis (COMSOL, ANSYS)**
  - **DAQ software (Labview version, C++ version)**
  - **FPGA (Altera, Xilinx) design workstations**
  - **FPGA Design platforms**

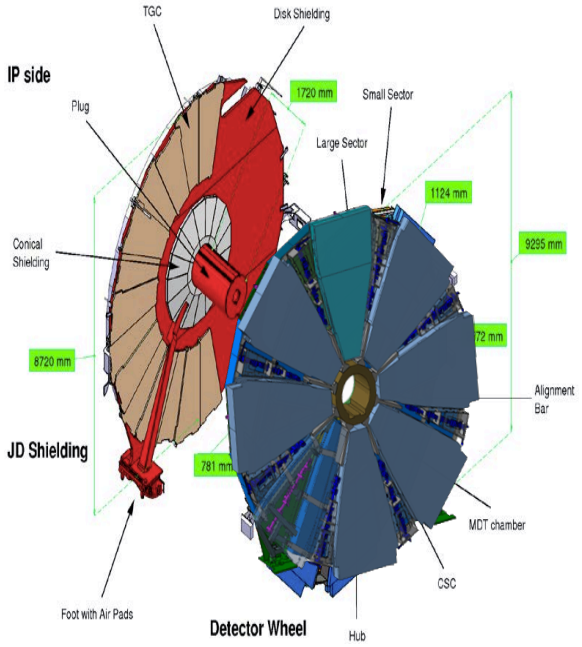
- **CLEAN ROOM (12 m^2 – two rooms Class 10,000 and Class 100,000)**
  - **Microscope**

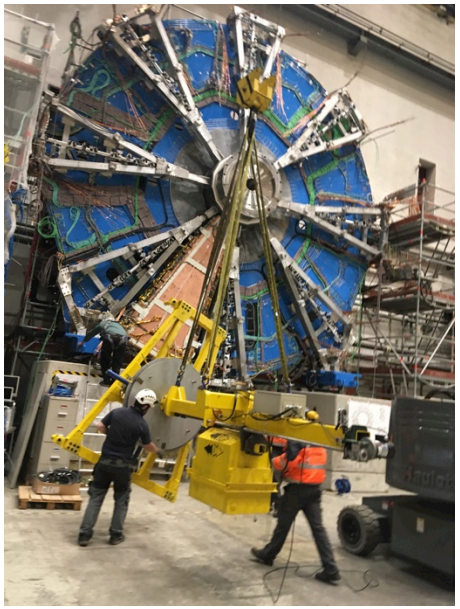
New Small Wheel (NSW) Layout

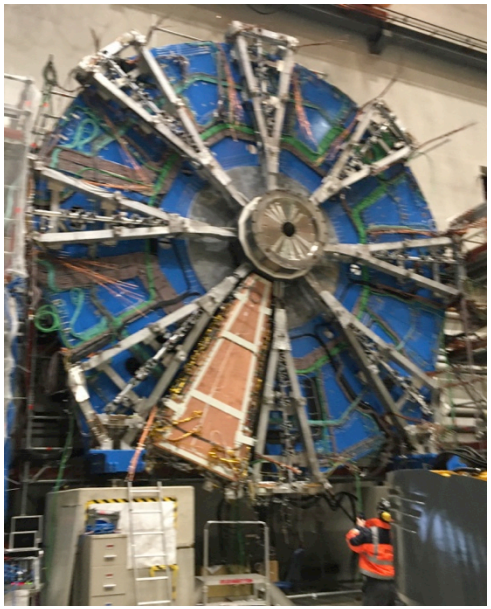
8 MM + 8 sTGC layers per NSW sector

- Two technologies: Both Micromegas & sTGC detectors will provide tracking and trigger data
- 16 Sectors per Wheel (8 large, 8 small)
- 2 Multilayers (Modules) per Sector for Micromegas & 3 Multilayers (Modules) per Sector for sTGC
- 8 Micromegas Layers & 8 sTGC Layers per Multilayer



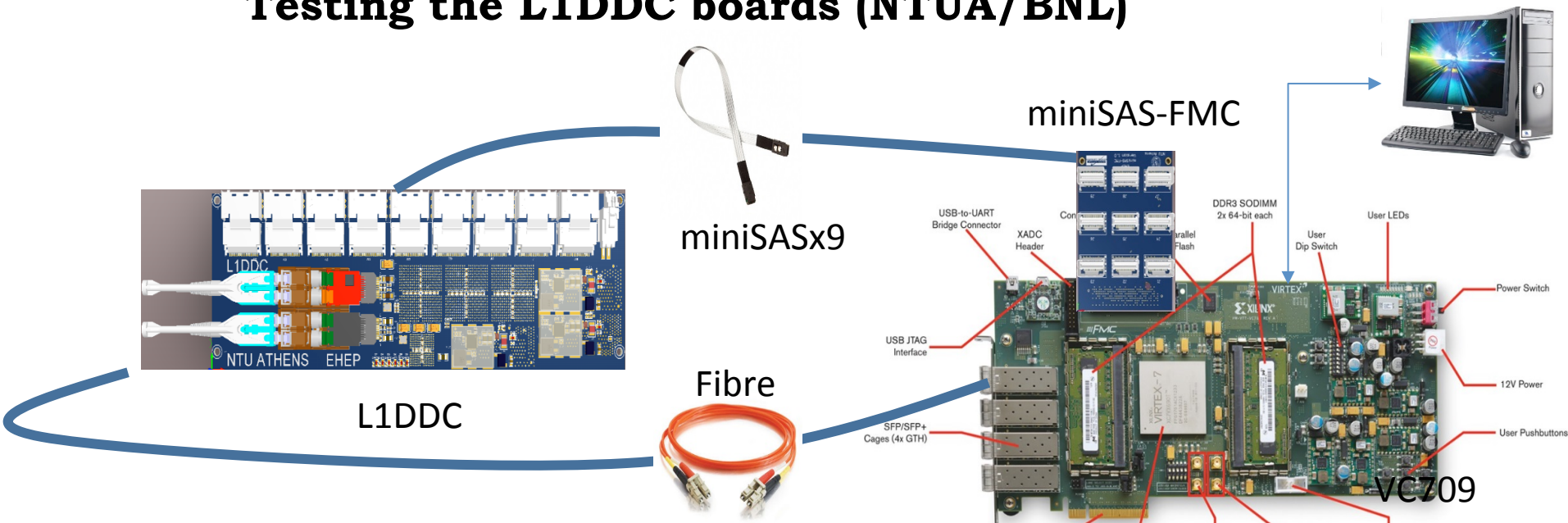






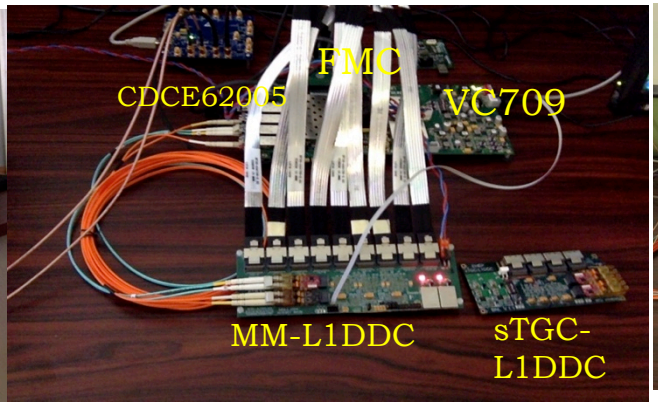
sTGC (mainly for triggering) & Micromegas (mainly for tracking) detectors, both providing tracking and triggering information, combined into a fully redundant NSW system!

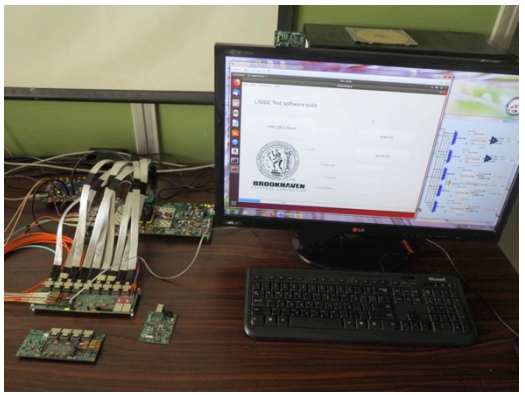
Testing the L1DDC boards (NTUA/BNL)



- Use an evaluation VC709 board and GBT-FPGA firmware to validate the L1DDC boards
- Evaluation board runs GBT-FPGA firmware along with E-Links
  - Data are generated in VC709 with respect to that clock and send to L1DDC via E-links and then through fiber back to the evaluation board

Test setup at Demokritos

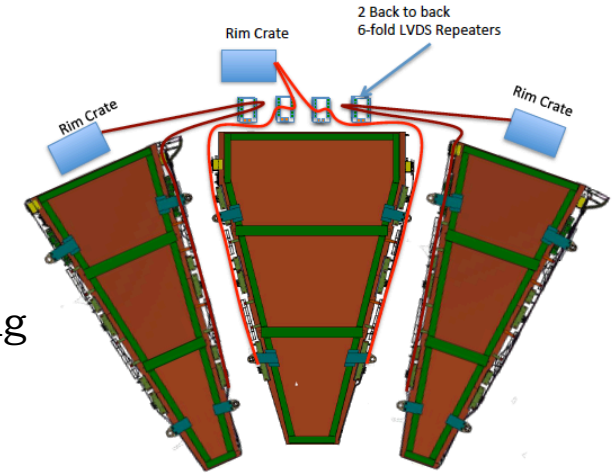




NCSR Demokritos group responsibilities

B) The sTGC Repeaters Boards design, construction, commissioning and Integration. (Current major Project, Sept. 2018 – today)

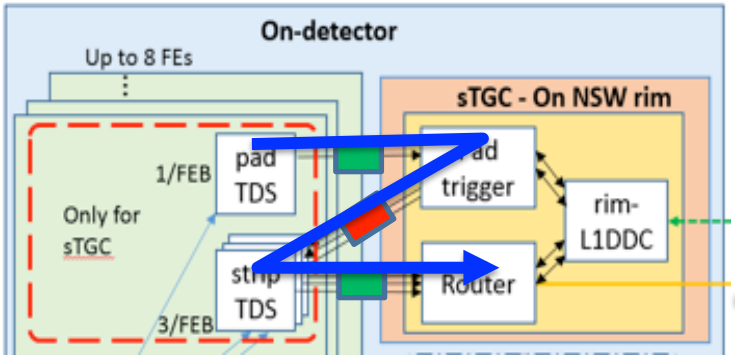
- **Repeaters design**
- **Construction and testing**
- **Commissioning and integration**



Problem addressed

1) High rate signals are attenuated at long transfers (~6.5m)

2) We need repeater cards to boost the signals to the receiving end. Critical for Trigger path.



Serial repeater 4.8Gb/s

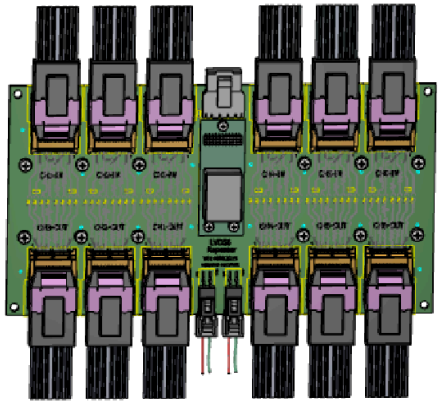
LVDS repeater 640Mb/s

Trigger Path

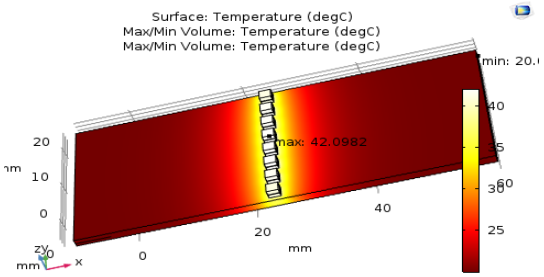
Frequency (GHz)	0.50	1.0	2.0	5.0	10.0	15.0	20.0
Tin Plating (dB/m)	-0.90	-1.4	-2.2	-4.0	-7.5	-10.9	-14.6
Silver Plating (dB/m)	-0.85	-1.2	-1.7	-3.2	-4.9	-6.8	-8.8
difference	-0.05	0.2	-0.5	-0.8	-2.6	-4.1	-5.8

Cable attenuation

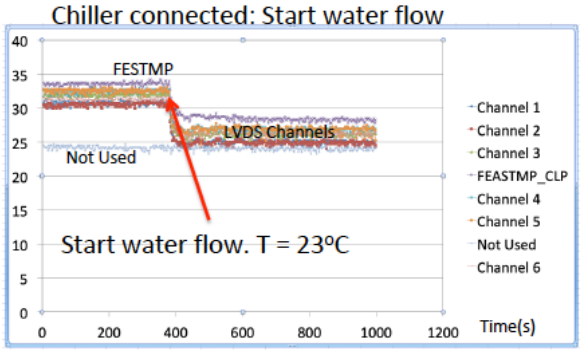
LVD6R Repeaters – LVD6R: Ελληνικές Εταιρείες
(Prisma: κατασκευή ηλεκτρονικών, Rentron: Κλωβοί Faraday

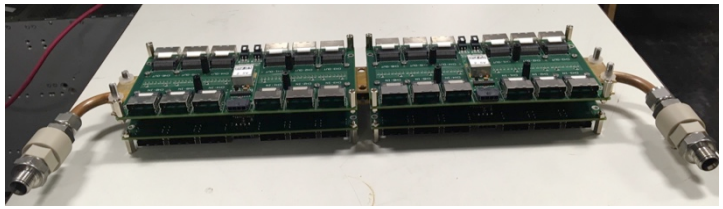


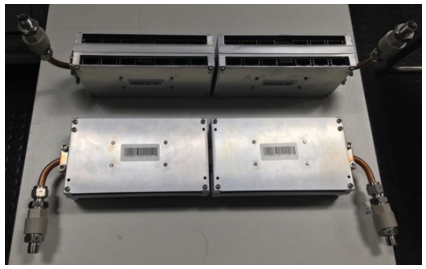
Comsol calculation of the T distribution – Cooling
Master Thesis by K. Damanakis

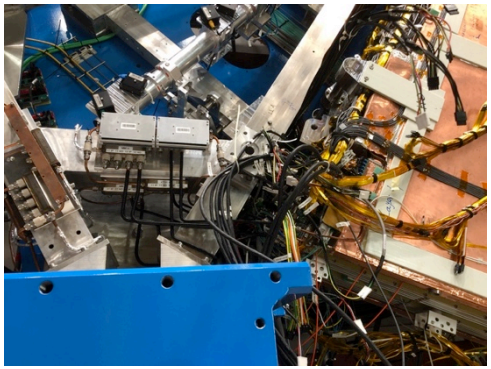


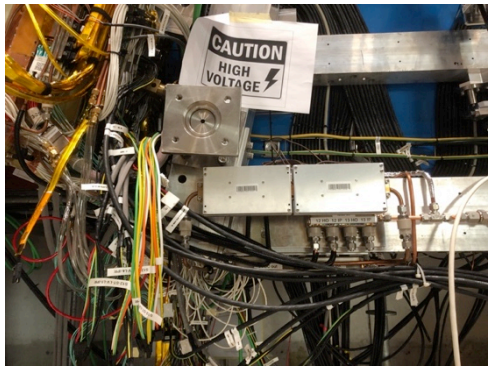
Effectiveness of cooling





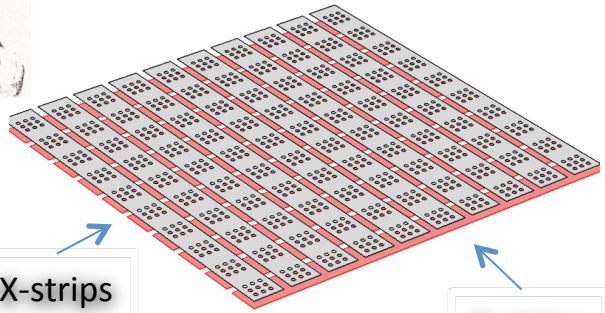


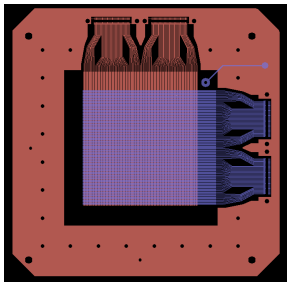




Τοποθέτηση μονάδων
Στο NSW/ATLAS

Real x-y Segmented Mesh Microbulk Micromegas



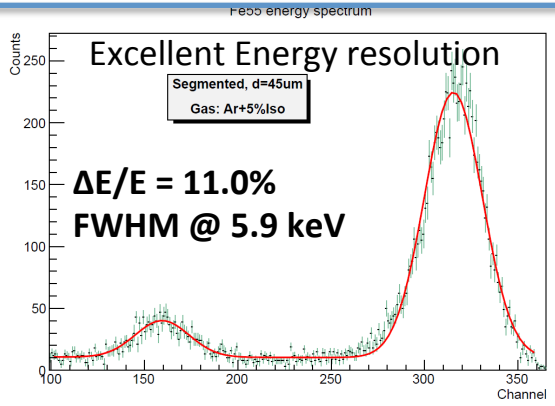


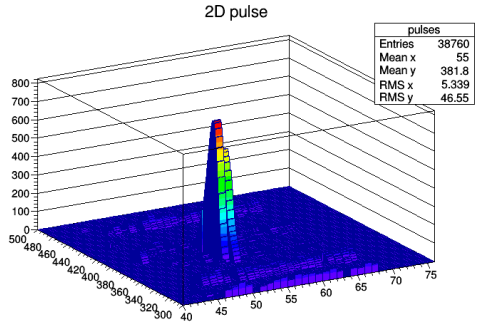
Large detector
7cm x 7cm

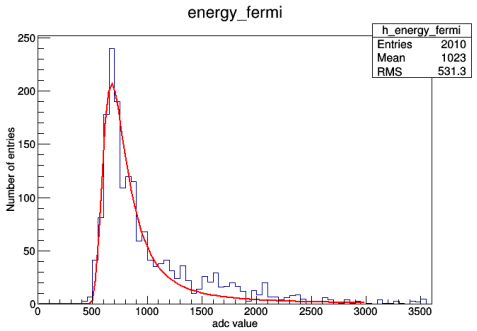
1) **Real x-y structure**
2) **Mass minimization**
3) **Production Simplification**

Ideal for:
1) **Rare searches (axion, dark matter)**
Background → ~ 10^{-7} cnts/keV/cm²/s
2) **Neutron Beam profiler (nTOF)**
Very low material Budget:

Current activity (2018 – 2019):
Real x-y microbulk with strip pitch 700 μm
Operation in TPC mode for tracking



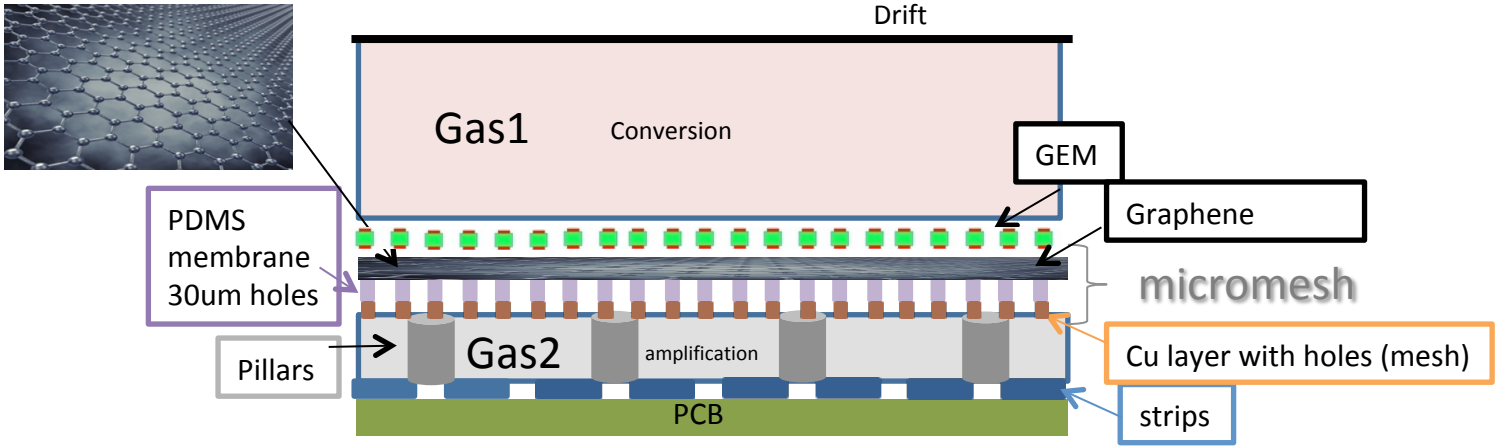




Strip wave form → x,y,z coordinates **Landau distribution from Cosmic muons**

M. Diakaki et al., "'Development of a novel segmented mesh MicroMegas detector for neutron beam profiling", NIMA 903(2018) 46-55.

R&D on Double gas Phase Micromegas

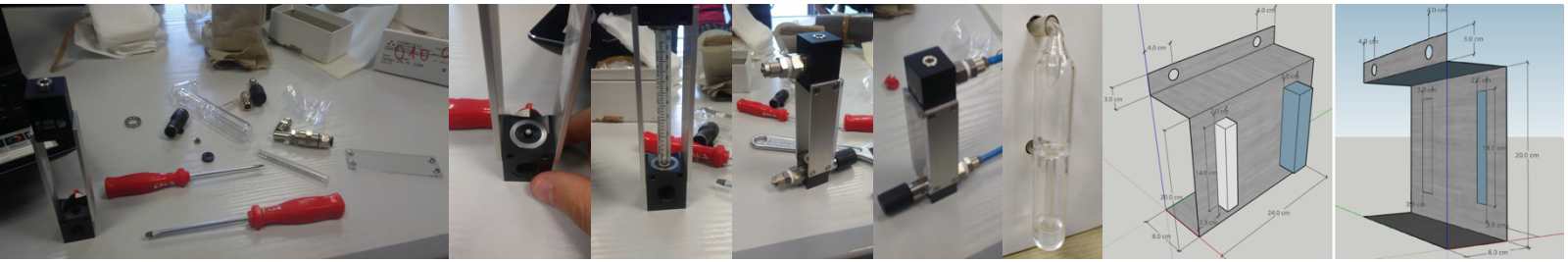


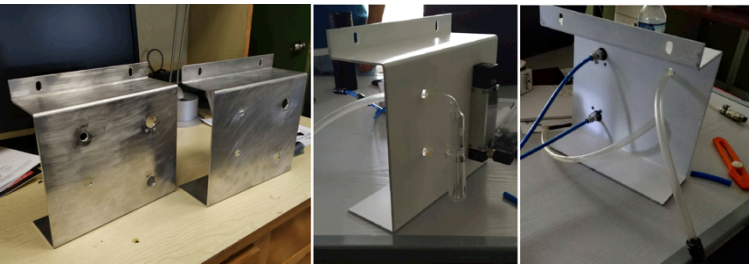
Our ambition:

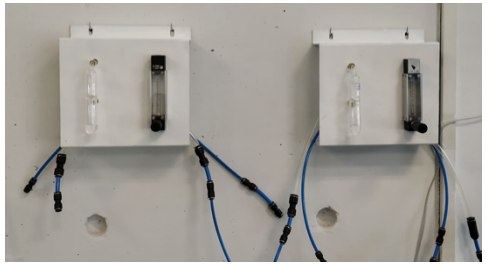
1) Two-gas phase detector separated by a Graphene layer
2) Exploit differences in gas properties to improve performance
3) Should have high electron transparency (test to be performed)
4) It may be used to eliminate ion backflow

Work by the Practical students: Stamatis Tzanos, Vasilis Blanas

Build 2 Gas Flow Controllers

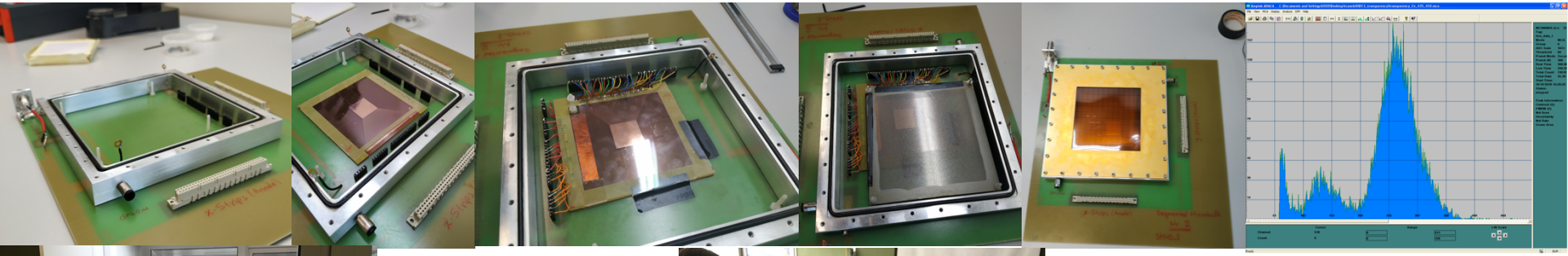






Excellent work
Done from A-Z

Work on the “Real x-y Segmented Microbulk”: First real x-y with 700 μm strip pitch



Working in the Clean Room

Preparing the Cloud Chamber For Researcher’s Night

Διδακτορικές Διατριβές

1) Ελένη Ντόμαρη, «Έρευνα για Υπερσυμμετρία με το πείραμα CMS σε τελικές καταστάσεις φωτονίων, πιδάκων και εγκάρσιας ελλείπουσας ενέργειας και ανάπτυξη οργανολογίας για τα πειράματα του LHC», ολοκληρώθηκε τον Ιανουάριο 2013, ΣΕΜΦΕ, ΕΜΠ.
2) Αθηνά Κουρκουμέλη-Χαραλαμπίδη, «Ενδείξεις για ύπαρξη υπερσυμμετρίας μελετώντας γεγονότα με 3 λεπτόνια και μεγάλη εγκάρσια χαμένη ενέργεια στο πείραμα ATLAS του CERN», 2015 Πανεπ. Αιγαίου

Master Thesis

1) Παναγιώτης Γκουντούμης, «Σχεδίαση κώδικα σε γλώσσα προγραμματισμού C++ για τη συλλογή δεδομένων από τον ανιχνευτή micromegas», NKUA, 2011
2) Γεράσιμος Βανδώρος, «Μελέτη ανιχνευτή Micromegas TPC και τρισδιάστατη ανακατασκευή των τροχιών παρουσία Μαγνητικού πεδίου», Ιούνιος 2013, ΣΕΜΦΕ, ΕΜΠ.
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5) Κώστας Δαμανάκης, «Development and construction of a gas mixing system for studying the performance of MicroMeGaS detector», NTUA, Ιούνιος 2019
6) Όλγα Ζορμπά, «Ανάπτυξη Ανιχνευτικού Συστήματος Κοσμικών Ακτίνων για τη Μελέτη Ανιχνευτή Micromegas», (NTUA), Ιούνιος 2019.

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3) Γιώργος Χάϊδας , Καλοκαίρι 2017, «Μελέτη ανιχνευτή Μικρομέγας και ακτινοβολήσεις με πηγές και ακτίνες Χ», ΣΕΜΦΕ, ΕΜΠ.
4) Σταμάτης Τζάνος, «Segmented mesh Microbulk Micromegas" (NTUA)
5) Βασίλης Μπλάνας «Segmented mesh Microbulk Micromegas" (NTUA)
6) Stathis Logothetis, Cosmic Stand (NTUA)
7) Eva Eleftheriou, Gas Mixer (Univ. Patras)
8) Despina Stasinou, Cosmic Stand (Univ. Patras)
9) Athanasia Papaioannou, Gas Mixer (Univ. Patras)

Διπλωματικές (Κύριος επιβλέπων)

1) Ασημίνα Κοβού, «Μελέτη ανιχνευτών Μικρομέγας με αντιστατική επικάλυψη για καλορίμετρα», Νοέμ. 2016, Πανεπ. Ιωαννίνων.
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4) Βασίλης Μπλάνας, «Μελέτη κοσμικών μιονίων με ανιχνευτές Μικρομέγας χρησιμοποιώντας Cosmic Stand", NTUA

Θέματα για εκπόνηση Master Thesis

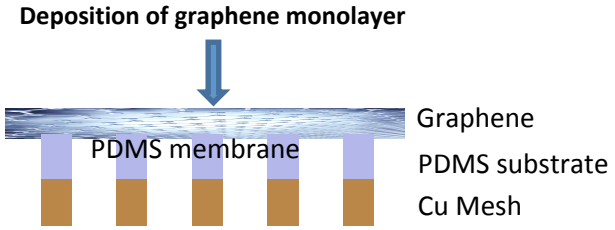
1) **Λήψη και ανάλυση δεδομένων με το νέο Ανιχνευτή Μιονίων New Small Wheel του πειράματος ΑΤΛΑΣ**
   - Εργασία στο Σύστημα Λήψης Δεδομένων (Data Acquisition)
   - Λήψη δεδομένων με κοσμικές ακτίνες
   - Μελέτη της απόδοσης των ανιχνευτών του NSW με κοσμικά μιόνια

2) **Μελέτη Ανιχνευτή Μικρομέγας του New Small Wheel για το πείραμα ΑΤΛΑΣ παρουσία νετρονίων**
   - Λήψη δεδομένων με ανιχνευτές Μικρομέγας τύπου NSW με αντιστατική επικάλυψη
   - Μελέτη Μικρομέγας με κοσμικά μιόνια
   - Ανίχνευση Κοσμικών Μιονίων χρησιμοποιώντας Cosmic Stand (Veto σπινθηριστών) παρουσία μεγάλης ροής νετρονίων μέσα στην Tandem. Η ροή νετρονίων θα ρυθμιστεί να είναι ίδια με τις ροές στο LHC.

BACKUP

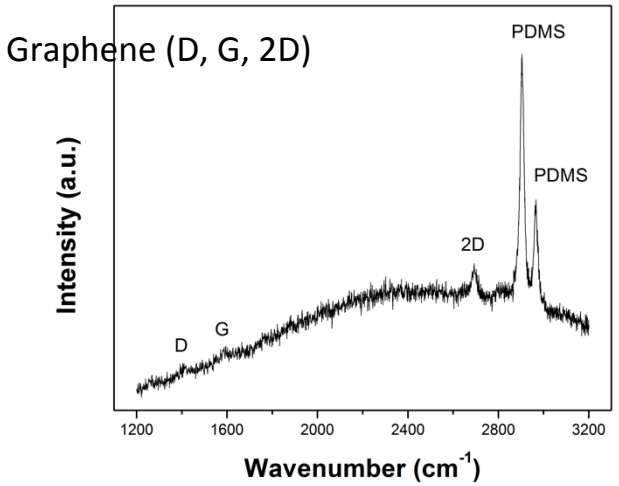
Transport Graphene on PDMS

i) Produce Graphene on Cu foil
ii) Cover it with PMMA
iii) Dissolve Cu
iv) Place PMMA+Graphene on PDMS
v) Dissolve PMMA



- Raman spectroscopy was used to confirm the graphene transfer uniformly on the PDMS membrane

We have placed a graphene surface of 1 x 1 cm^2 on to of the PDMS substrate



Future plans

1) Optimize technique for the Graphene – PDMS – mesh membrane
2) Add GEM foil and test electron transparency
3) Measure gas diffusion through Graphene
4) Possibly lay double or triple layers

SCREAM: Sampling Calorimetry with Resistive Anode MPGDs
Resistive Bulk Micromegas for High Rate applications

Collaboration

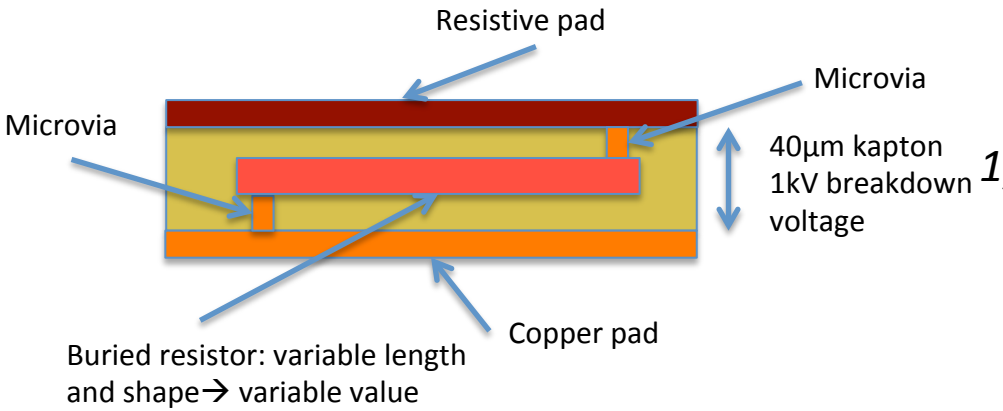
INPP
G. Fanourakis
T. Geralis

LAPP Annecy
M. Chefdeville
I. Karyotakis
2 Engineers

IRFU Saclay
M. Titov

Future Resistive Micromegas applications within ATLAS

1) At HL-LHC (ATLAS upgrade) Muon High-Eta Tagger
2) At the Future Circular Collider (FCC)



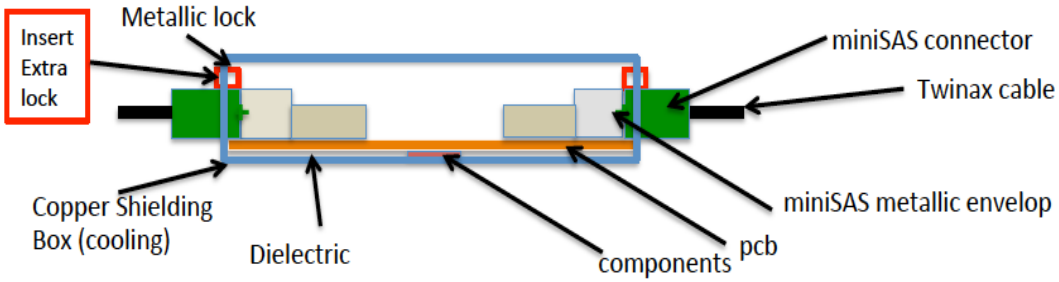
Optimization of Resistivity →

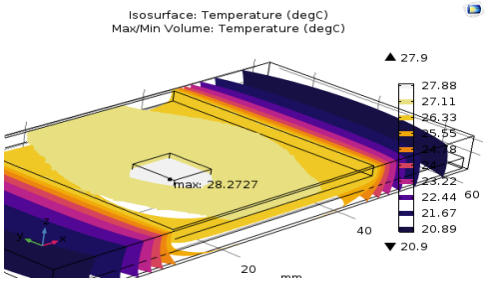
- **Excellent linearity at Rates:**
  0 - 10 MHz/cm²
- **No discharges**

1) *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)*
2) Publication in preparation (to be submitted to NIM). Test beam data in Nov. 2018

Shielding and Cooling

Copper box is designed as shielding and passive cooling at the same time





Temperature contour calculated using COMSOL with realistic power Dissipation and geometry
(See talk by K. Damanakis)

Temperature was monitored and agrees With the COMSOL calculation

Shielding Box with the Serial Repeater Assembled. Label with bar code produced from the database

VMM ASIC irradiation studies (2013 – 2018)

Collaboration
INPP: A. Kourkoumeli (PhD), G. Fanourakis, T. Geralis
NTUA: T. Alexopoulos, M. Kokkoris, G. Tsipolitis
Aegean Univ.: K. Papageorgiou, I. Gialas

VMM will be used at the s-LHC➔ Should test radiation tolerance and SEU ASIC specifications: 130 nm Technology, 64 channels, BNL design

VMM will be used by ATLAS muon Micromegas group and also as the SRS FE chip

Irradiation took place at the Tandem Accelerator

Credits: T.Alexopoulos

Nuclear Reaction	Energy Range (MeV)	Range (MeV)
$^{7}Li(p,n)^{7}Be$	1.9 to 8.4	0.1 to 6.7*
$^{2}H(d,n)^{3}He$	0.8 to 8.4	3.9 to 11.5**
$^{3}H(d,n)^{4}He$	0.8 to 8.4	16.4 to 25.7***

[0.1,0.5] MeV & quasimonoenergetic up to ~2.5 MeV
** Quasimonoenergetic neutrons up to ~7.5 MeV
*** Monoenergetic neutrons [16.4,22] MeV

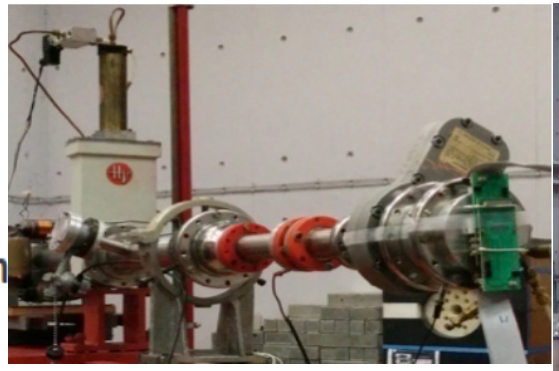
Tritium target (10 ci):

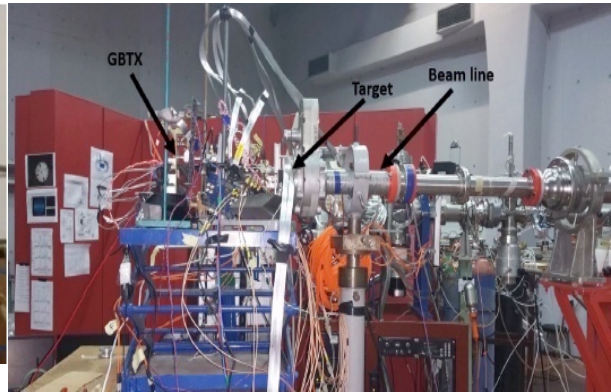
~10^{6} neutrons/cm^{2}s of 18-22 MeV

Testing:

2 days @ E_d = 5.5 MeV, VMMs @ 26,36 mm

3 days @ E_d = 4 MeV, VMMs @ 12,21 mm





NCSR Demokritos group responsibilities

D) Reconstruction software for the Muon and the NSW system (July 2019 – today) -- see George Stavropoulos talk

- **Development of the NSW reconstruction software and porting of the whole Muon Reconstruction software in multithreading.**

E) R&D on Micromegas operation (ongoing)

- **SRS readout system -- see talk by Vassilis Blanas**
- **Cosmic Stand system -- see talk by Olga Zormpa**
- **Cosmic muon detection under neutron irradiation**

F) sTGC Trigger Chain and the Chiller system (Oct. 2019 – Dec. 2019)

- **Build autonomous station of Front End cards + Trigger boards + + Felix**
- **Build the cooling system for the sTGC commissiong site**

G) Irradiation tests in Tandem

CONCLUSIONS

INPP/ATLAS Group has undertaken important responsibilities within the NSW project:

- QA/QC of 200 L1DDC cards (1/4 of the total) and 600 ADDC cards (full production)

- Full responsibility of the Serial (SRL1R) and LVDS (LVD6R) Repeaters

- Finalized design, Completed preproduction, Laboratory and on detector testing
- Completing Final Production of SRL1R and half of the LVD6R production

- **Plays major role on the Muon System and the NSW Reconstruction software**
  - Porting of the Muon software to Multithreading mode
  - New code for NSW in Multithreading

- Plays important role in the commissioning of the sTGC

- Cooling systems manufacturing, testing, electronics, Trigger system

Plans:

- Commissioning and Integration of the Repeaters on the NSW
- Participation in the Commissioning of the sTGCs and the Micromegas
- Development within the Trigger and DAQ system in NSW

R&Ds ongoing with lower priority in ELEA:

1) Real x-y microbulk, 2) Resistive μM for High rates 3) Picosecond Micromegas
4) Double phase Micromegas with Graphene