The ATLAS/LHC Demokritos group research activities

Theodoros Geralis
NCSR Demokritos
5/5/2023

OUTLINE

- **The ATLAS New Small Wheel Muon Upgrade**
  - **sTGC Trigger/Detector**
  - **NSW Software development**
  - **Physics Analysis: Z mass**

- **Instrumentation Laboratory DAMA**
  - **Resistive Micromegas R&D**
  - **Picosec Micromegas**
  - **Real x-y microbulk micromegas**
  - **Micromegas and use of graphene**

FTE Students meeting
5 May 2023, NCSR "DEMOKRITOS", Athens, Greece

The ATLAS Group – 2023

NCSR Demokritos **full member** of **ATLAS** since Oct. 2017

Researchers

Georgios Fanourakis (Emeritus)	: gfan@inp.demokritos.gr
Theodoros Geralis (Team representative)	: geral@inp.demokritos.gr
Georgios Stavropoulos	: stavrop@inp.demokritos.gr
Andreas Psallidas	: Andreas.Psallidas@cern.ch

Doctoral Students

Olga Zormpa

Master Thesis

Afroditi Machaira

Technician (Electronics)

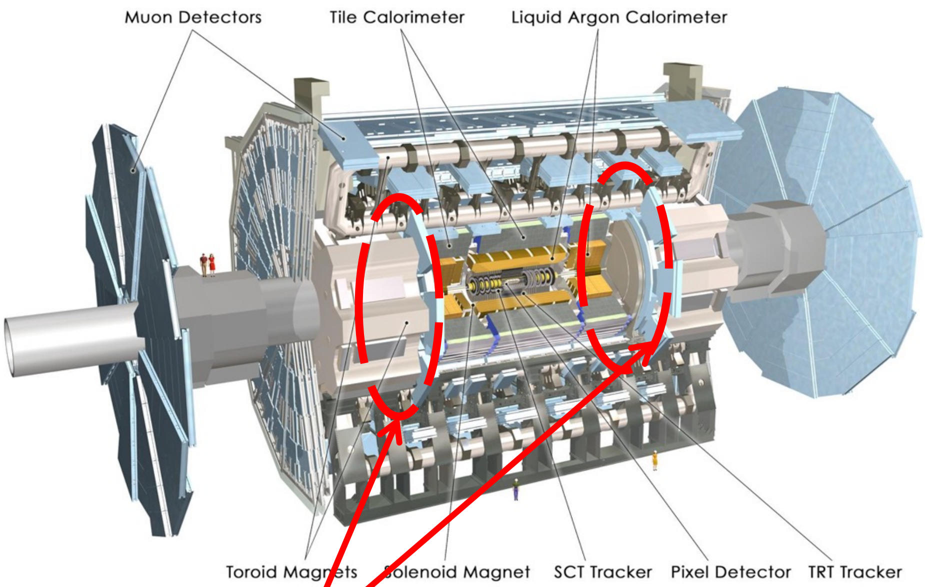
Yannis Kiskiras

Practical work at DAMA (2022)

Argiris Kerezis, Univ. of Ioannina

Ilias Alexopoulos, Univ. of Athens

The ATLAS Experiment - Upgrade

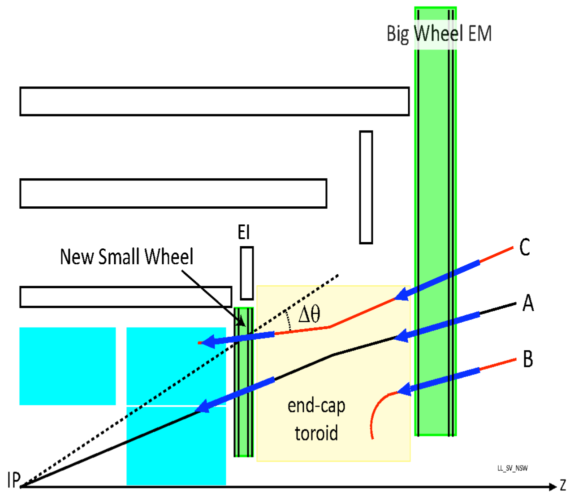


- ATLAS - General purpose detector
- Muon Small wheels:
  Between the End-cap Calorimeter and End-cap Toroid
- 10 m in diameter
- Consist of:
  - Cathode Strip Chambers (CSC)
  - Thin Gap Chambers (TGC)
  - Monitor Drift Tube (MDT)
- Coverage: 1.3 < |η| <2.7

Small Wheels

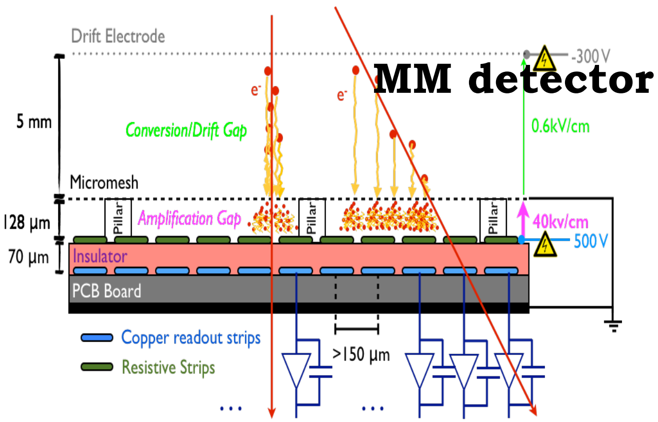
NEW SMALL WHEELS
Mechanical structure

Operation principle MMs and sTGC (NSW Technologies)

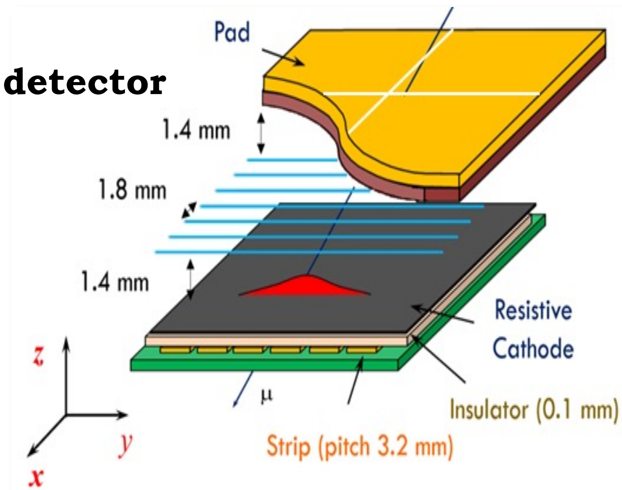


New Small Wheels (NSW)

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



sTGC detector



Micromegas – 2.1 Million Channels

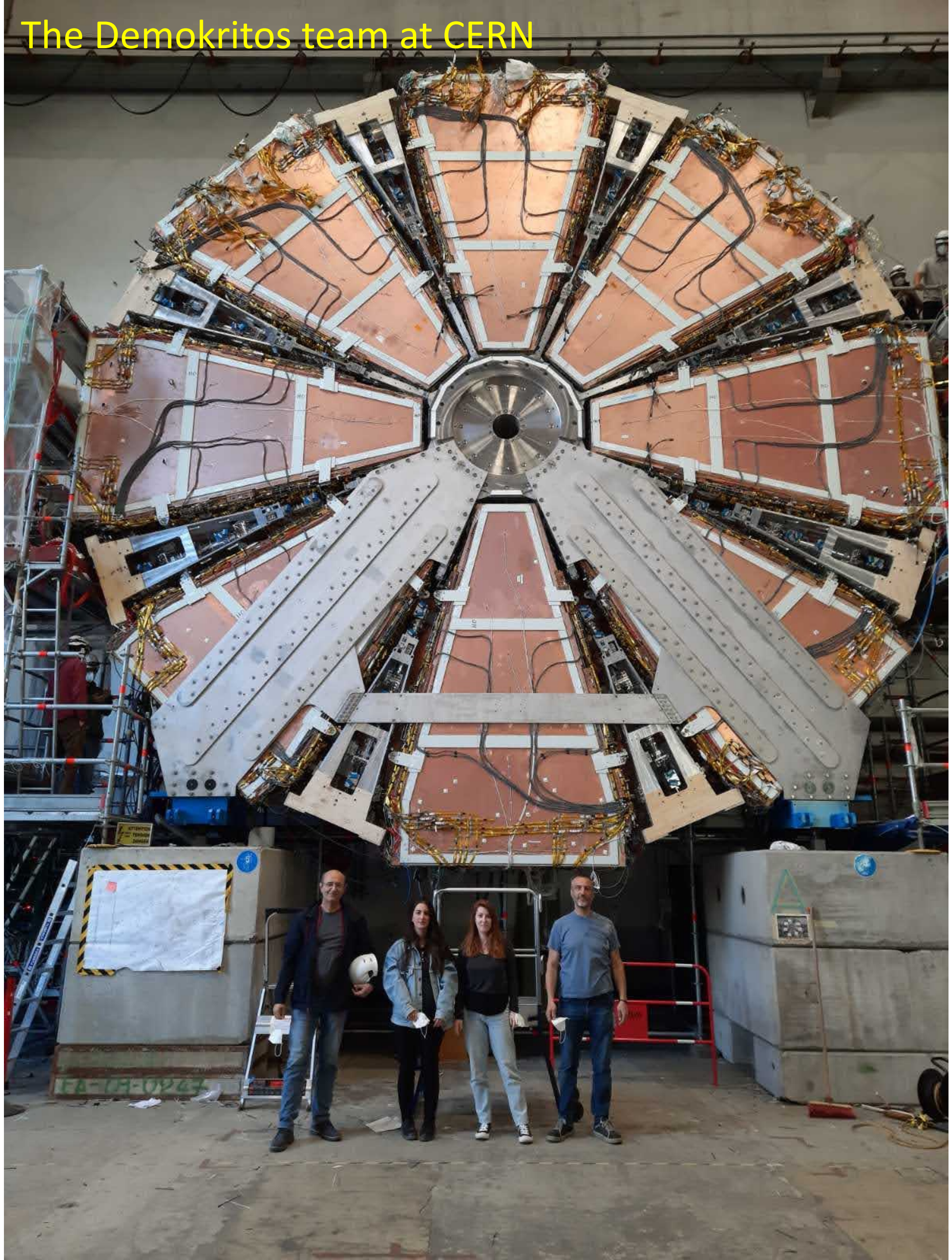
MM strips for tracking, first hit for trigger

-Strip pitch: 450 μm
-Precision: ~ 100 μm/layer
-Data rates: Up to 8 Gbps/plane

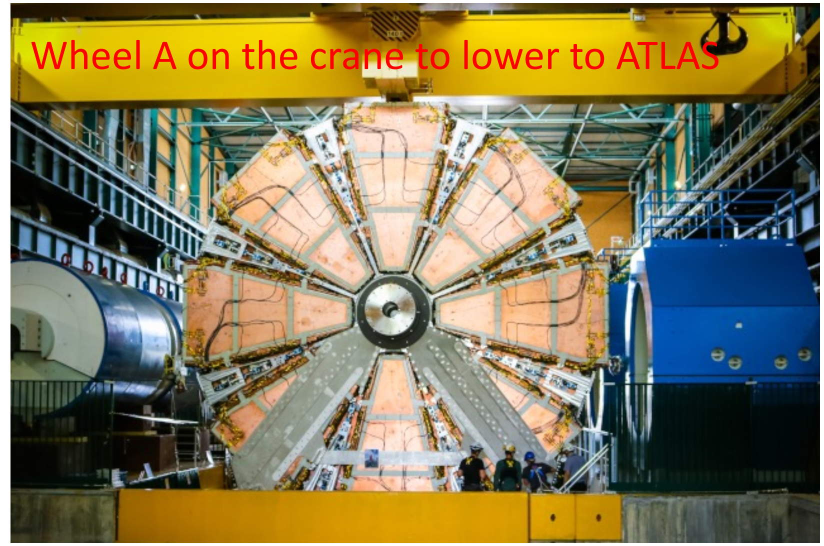
sTGC – 330 k Channels

- sTGC wires/strips for tracking, strips/pads for trigger
  - Precision: ~ 100 μm/layer
  - Data rates: up to 1.77 Gbps/plane

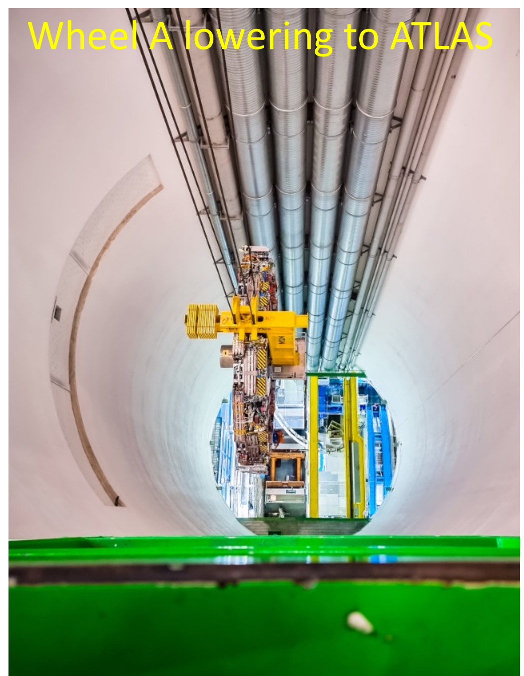
The Demokritos team at CERN

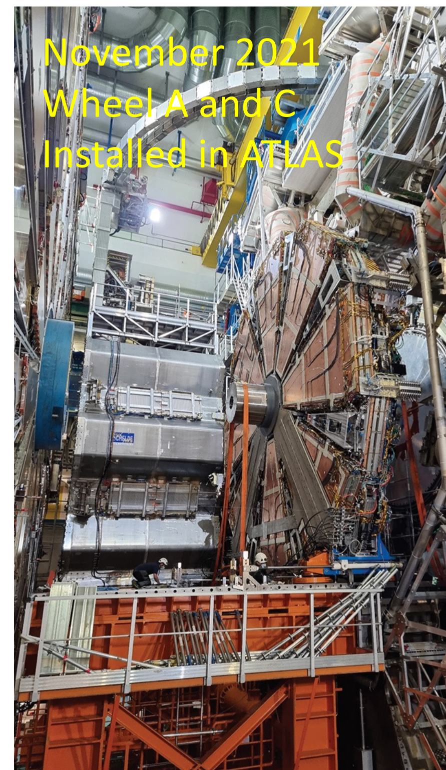



Wheel A trasported to P1/ATLAS

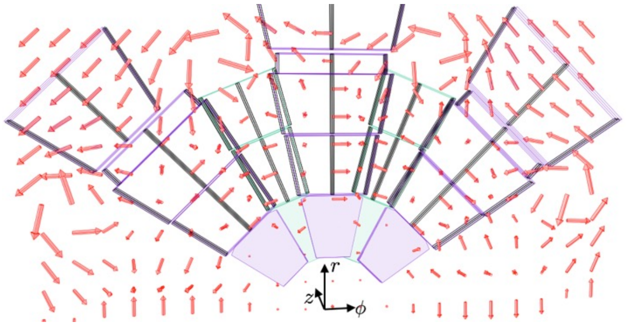

Wheel A on the crane to lower to ATLAS


Wheel A lowering to ATLAS


Wheel A lowering to ATLAS


November 2021
Wheel A and C
Installed in ATLAS

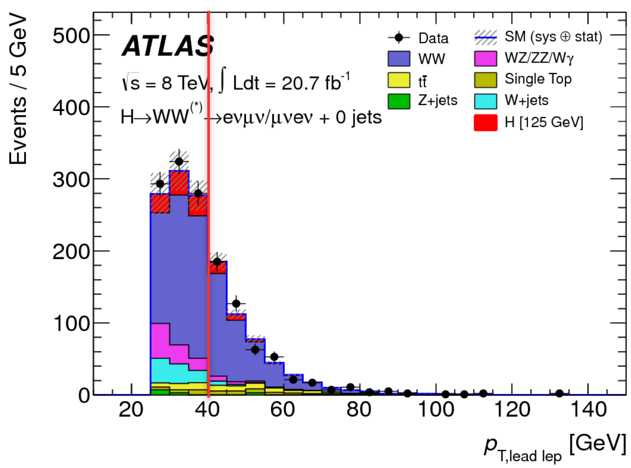
NSW: Impact on Physics

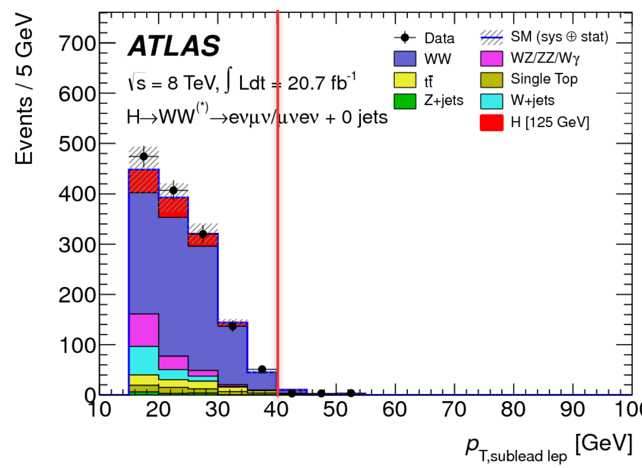


- Toroid Magnetic field requires dense tracking ➔ NSW
- Possibility for proper reconstruction to the IP and resolve pile-up events (up to 150 in HL-LHC)
- Reconstruction of μ P_T~10 GeV
- Keep efficiency and acceptance very high > 90% at HL

- Trigger rates without NSW:
  P_T > 40 GeV ➔ single μ- Trigger rate 60kHz
- Trigger rates with NSW:
  P_T > 20 GeV ➔ single μ- Trigger rate 20kHz
- Can keep lower P_T (>10GeV) subleading μ

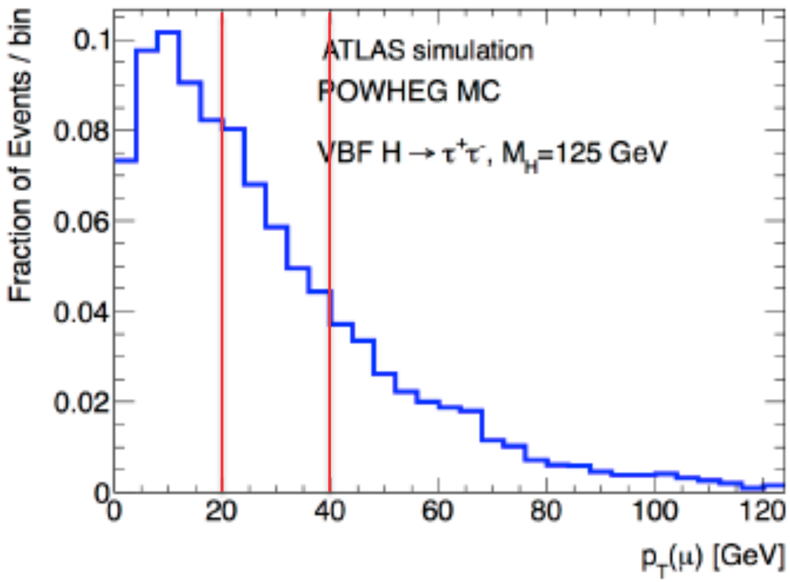
Example: H→WW*→lνlν





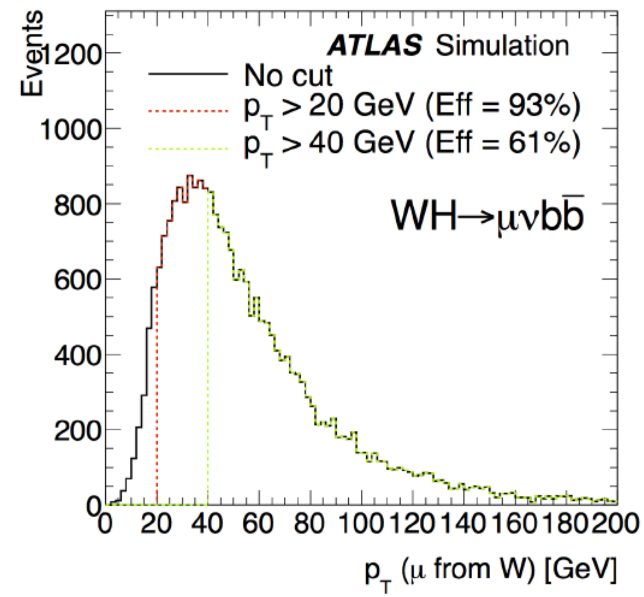
A P_T cut at 40 GeV would suppress most of the signal

Higgs production by VBF: Lower cross section but distinct signature



Higgs coupling to Vector Bosons Via Higgs-strahlung: pp→ WH

Trigger on leptons from W decays



High P_T (>100 GeV) μ require high precision and high efficiency tracking

NSW: 16 layers, high efficiency in high occupancy

Allow physics channels with high mass Z', W', Higgs boson A decaying to muons

ATLAS

Η ομάδα του ΙΠΣΦ/ΕΚΕΦΕ Δημόκριτος έχει αναλάβει σημαντικές υπευθυνότητες στο πείραμα ΑΤΛΑΣ INPP:

Muon System software coordination, NSW Trigger, Physics Analysis

Προσφέρεται ένα θέμα για εκπόνηση Διπλωματικής Μάστερ:
«Πρόταση μελέτης διαδικασίας Φυσικής σε συγκρούσεις pp στο LHC στο κανάλι ……»

ΣΚΟΠΟΣ: Η διερεύνηση μελέτης νέας Φυσικής στο LHC με το πείραμα ATLAS

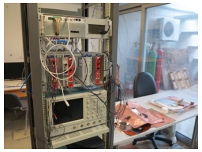
Πρόγραμμα:

1) Επιλογή καναλιού Φυσικής - αντίκτυπος π.χ. Τριπλή ζεύξη Higgs
2) Θεωρητικός υπολογισμός, ενεργός διατομή σε πρώτη τάξη – βιβλιογραφία
3) Εκμάθηση και χρήση γεννήτορα γεγονότων σε επίπεδο 4-διανυσμάτων
   - Βελτιστοποίηση και επιλογή παραμέτρων
   - Διερεύνηση διαγραμμάτων Feynman μεγαλύτερης τάξης
4) Παραγωγή γεγονότων με μεγάλη στατιστική και μελέτη κατανομών: Τύποι σωματιδίων τελικής κατάστασης, κατανομές εγκάρσιων ορμών, Ενεργειών, Σημείων διάσπασης κλπ
5) Μετασχηματισμός των παραπάνω κατανομών με μεθόδους Monte Carlo, που απορρέουν από την ακρίβεια μέτρησης των παραμέτρων (e.g. Energy smearing)
6) Εισαγωγή κύριων διαδικασιών υποβάθρου που θα επηρεάσουν τη μελέτη της κύριας προς μελέτη διαδικασίας
7) Επιλογή περιορισμών στις κατανομές (πχ E(electron) > 20 GeV, muon Pt > 10 GeV) Που θα προταθούν για χρήση από το σύστημα επιλογής των γεγονότων σε πραγματικό Χρόνο (σκανδαλισμός – Trigger)
8) Στατιστική ανάλυση για την ανάδειξη του σήματος

DAMA instrumentation RD

DAMA INFRASTRUCTURE

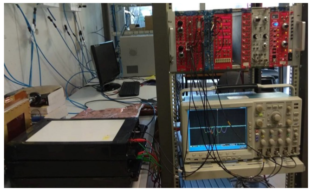
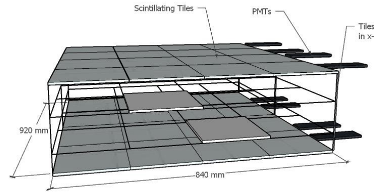




- **THREE FULLY EQUIPPED TEST BENCHES FOR STUDYING MPGDs**
  - **Electronics Rack, Gas distribution, Workstation, Osciloscope**

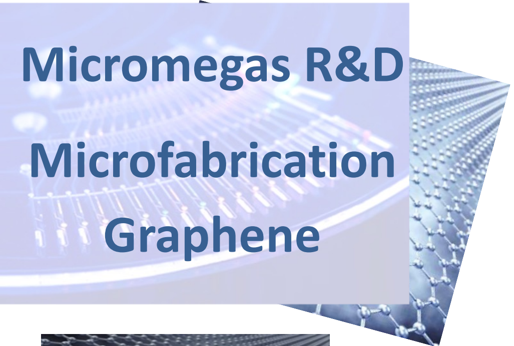
- **NEW GAS MIXER and distribution of premixed gases (K. Damanakis)**
  - **Mixing 3 gases**
  - **Operate at pressure range 100 mbar – 2 bar**

- **ELECTRONICS AND DAQ SYSTEMS**
  - **VME Data Acquisition (Controller, CRAMS, sequencer, ADC, Gate gen.**
  - **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**
- **DESIGN PACKAGES**
- **COSMIC STAND (Olga Zormpa, George Stavropoulos)**
  - **Scintillator based cosmic veto for triggering on muons**
  - **Used for studies of the Micromegas**

- **CLEAN ROOM (12 m² – two rooms Class 10,000 and Class 100,000)**
  - **Microscope**

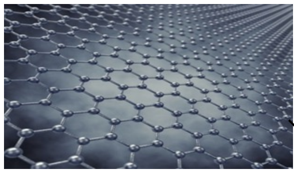
Examples of Students works

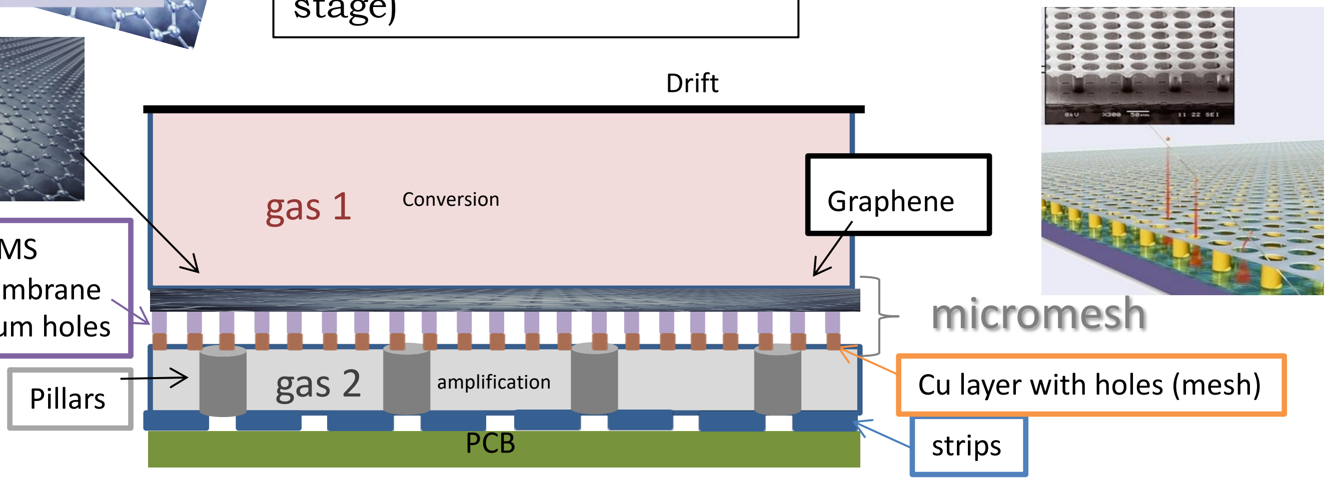


Micromegas Detector microfabrication

Aim: Build Micromegas Using microfabrication Techniques and Graphene (Proof of principle at this stage)

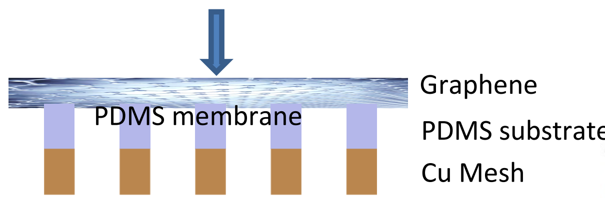
Collaboration (INPP, INN, ITE Patras):
T. Geralis, A. Tserepi,
A. Dimoulas, I. Parthenios



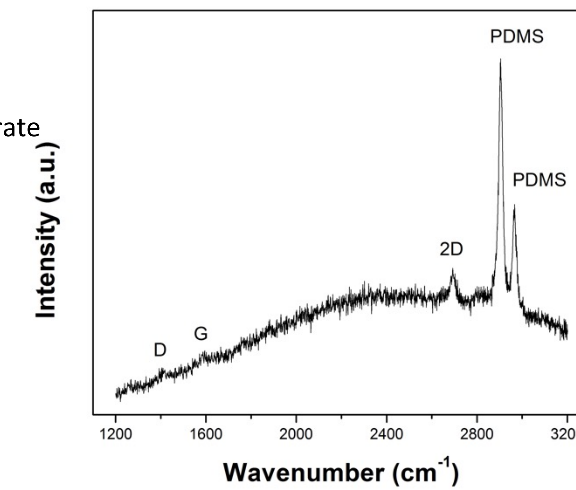


This is our ambition

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



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



ATLAS Local Trigger Interface (ALTI)

ALTI : Double VME board **Upgrade** to the current timing, trigger and control (TTC) system

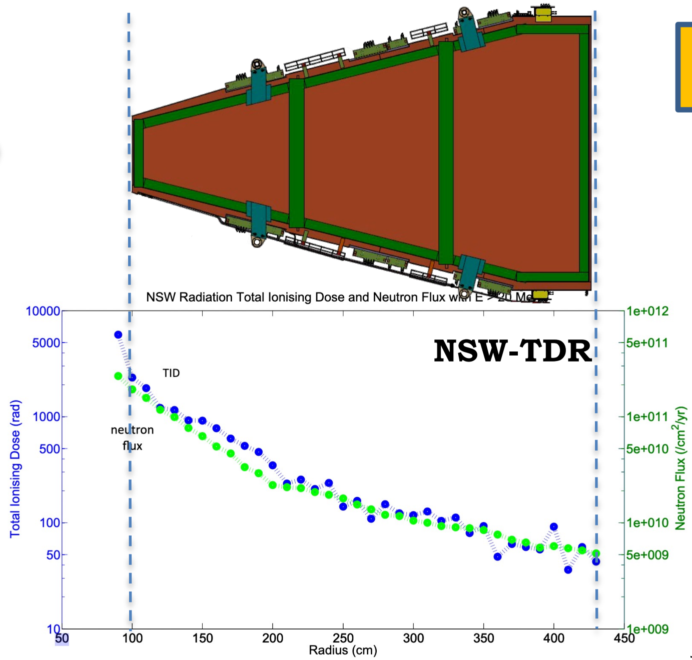
Primary function: Interfaces the Level-1 **Central Trigger Processor** and the **TTC network** to the front-end electronics of each of the ATLAS sub-detector

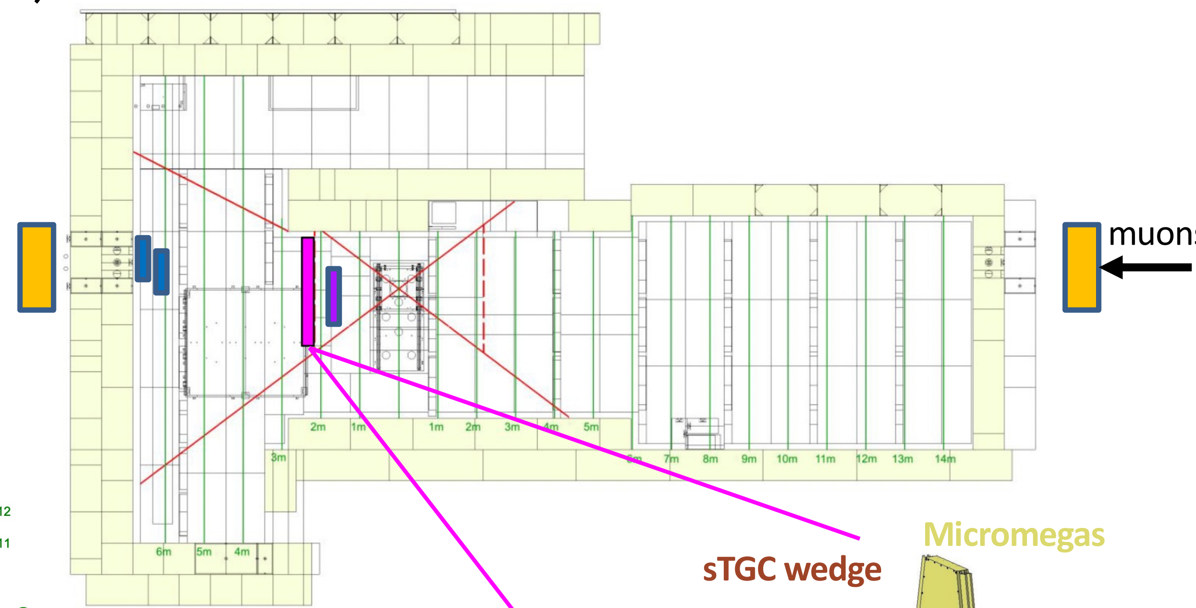
Currently provides an artificially generated pulse pattern with the **TTC information** and the **Bunch Crossing clock** at 40 MHz for data synchronization.

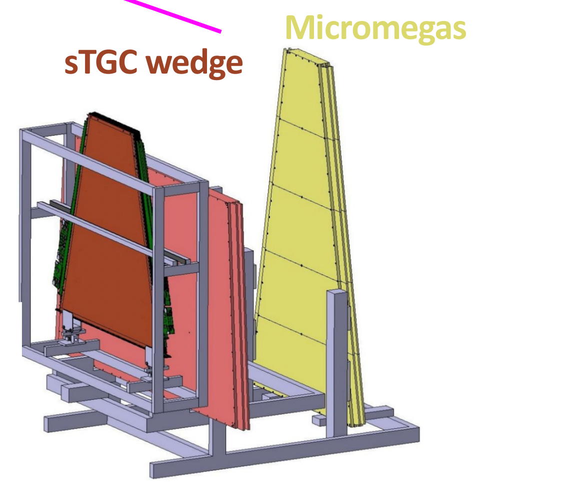
```
#----------------------
#                     M
#                     u
#                     l
#                     t
#                     i
#                     p
#                     l
#   CCC               i
#  BRRR    T BBBB TTT  c
#O UEEE    T GGGG TTTL i
#R SQQQ    Y 0000 RRR1 t
#B Y210    P 3210 321A y
#----------------------
 1 0000 0x00 0000 0000 40   # orbit signal
 0 0000 0x00 0000 0000 11
 0 0000 0x00 0000 0000 1    # BCR signal
 0 0000 0x00 0000 0000 99
 0 0000 0x00 0100 0000 1    # test pulse signal
 0 0000 0x00 0000 0000 69
 0 0000 0x00 0000 0001 1    # L1A signal
 0 0000 0x00 0000 0000 3342 # LHC orbit of 3564 BC -> 11.245 kHz
 1 0000 0x00 0000 0000 40
 0 0000 0x00 0000 0000 11
```

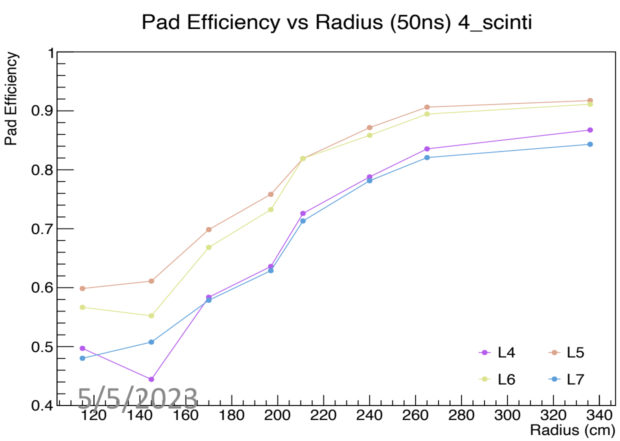
Irradiation tests at GIF: Gamma Irradiation Facility

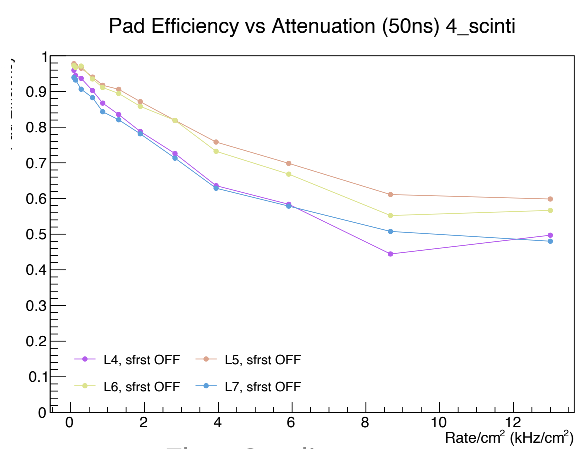
- **Irradiation with γ (^{137}Cs 662 keV) at LHC expected fluxes**
- **Aim: 1) measure μ efficiencies under irradiation**
  2) Measure fake rates











Gas Mixer System in ELEA

Designed by T. Geralis, developed by Kostas Damanakis, Athanasia Papaioannou.

Goals

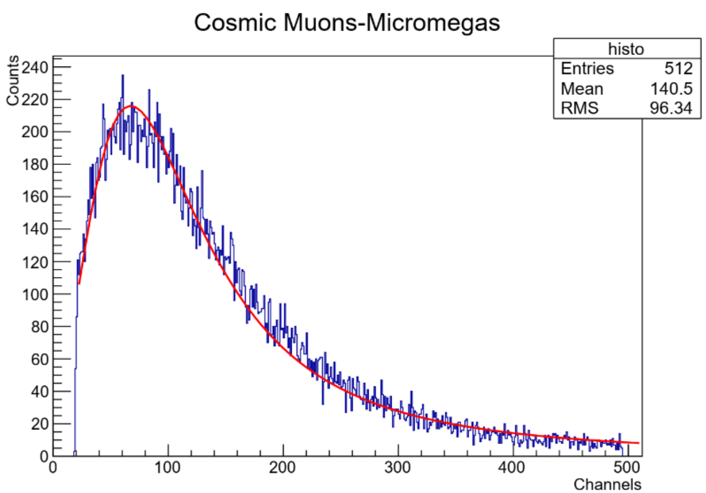
- Mixing three different gases and filling the Micromegas Detector with the gas mixture
- Choosing to mix the gases with the mixing system in order to minimize the imperfections that could possibly exist in industrially developed gases
- Study and improve the efficiency of the MMs under different gas mixtures

Cosmic Stand

Eva Eleftheriou, Stathis Logothetis (Practice students), Olga Zormpa (Masters student)

Goal: Design, set up and installation of a cosmic stand. **Purpose:** Reconstruction of muon tracks. Test and calibration of detectors (mainly MicroMeGaS)

Cosmic Stand + Micromegas Detector



FCN=667.556 FROM MIGRAD STATUS=CONVERGED 111 CALLS 112 TOTAL					
EDM=2.58823e-007 STRATEGY= 1 ERROR MATRIX UNCERTAINTY 2.0 per cent					
NO.	NAME	VALUE	ERROR	STEP SIZE	DERIVATIVE
1	Constant	1195.360000	9.686580	-0.275756	0.000120
2	MPV	74.530200	0.488637	0.005695	-0.000465
3	Sigma	32.518700	0.257339	0.000014	0.280630

Callibration with Fe-55: Channel 351 → 5.9 keV

Landau MPV: **channel 75 → E_{mu}=1.26 keV**

$\{\chi^2 = \frac{\text{FCN}}{\text{ndf}} = \frac{667.556}{509} = 1.3/\text{df}\}$

2.44 keV/cm→ **$E_{mu,th}$=1.22 keV**

15/11/2019 8

Monitoring of DAMA lab environmental variables

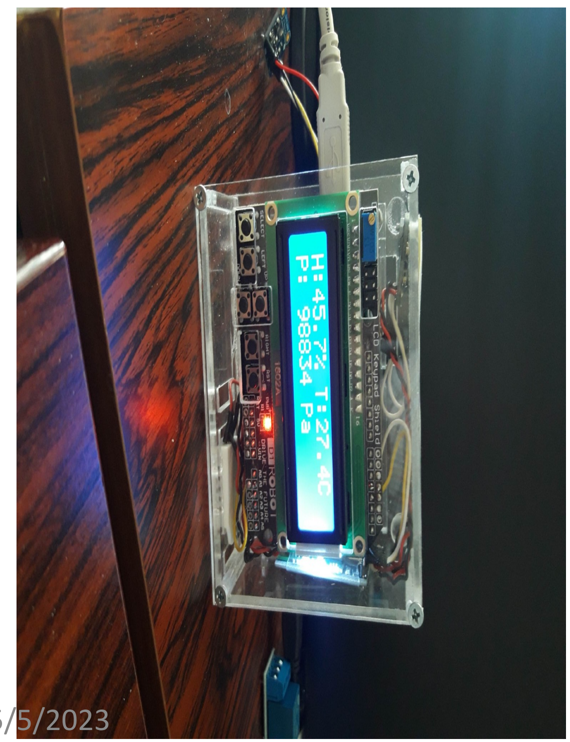
<u>Practice Students</u>: Alexopoulos I., Giannakopoulos D., Remoundou Th.

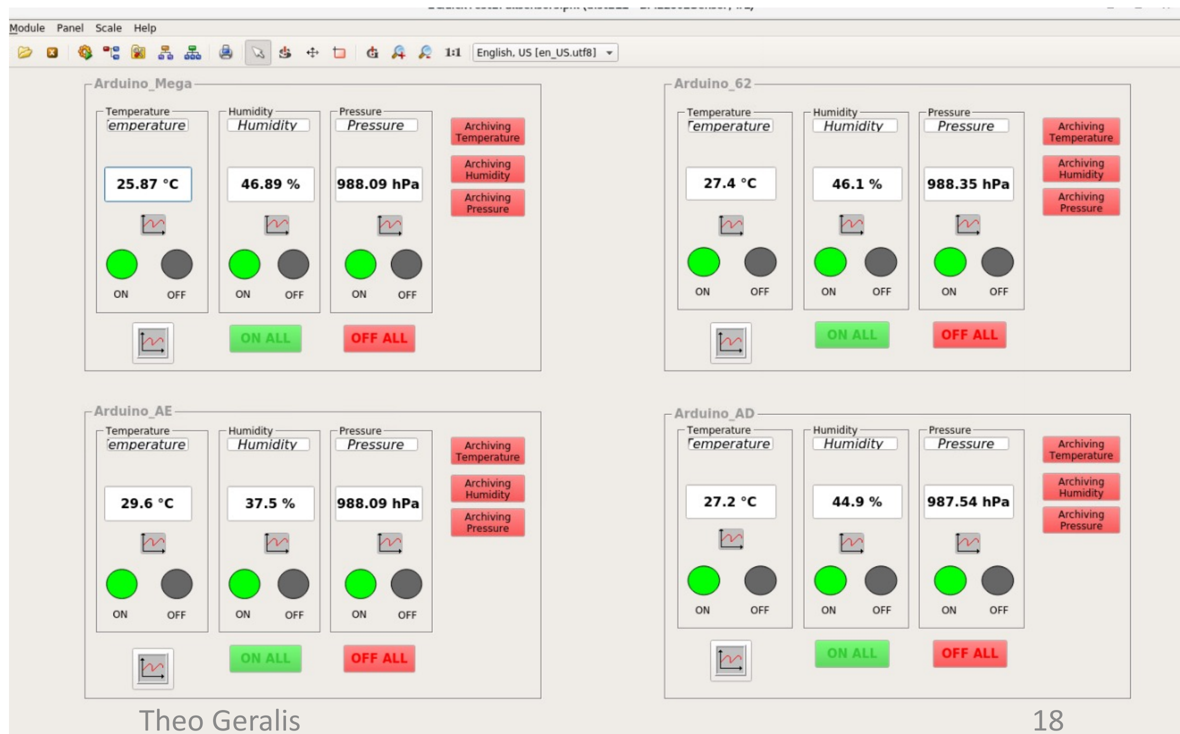
<u>Masters Student</u>: Kannelos N. <u>Technician</u>: Kiskiras I.

4 Arduino-based modules designed and constructed.

PC communication via Bluetooth (3 modules) and USB (1 module)

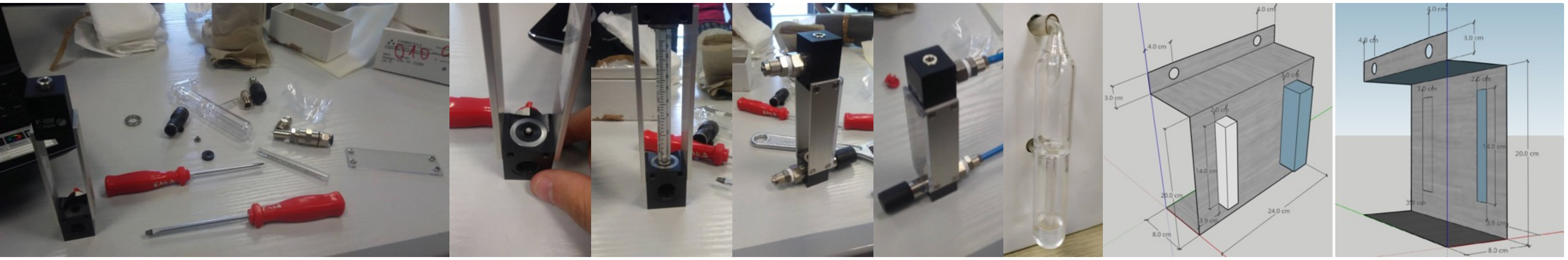
Commercial sw (WinCC) used for monitoring.

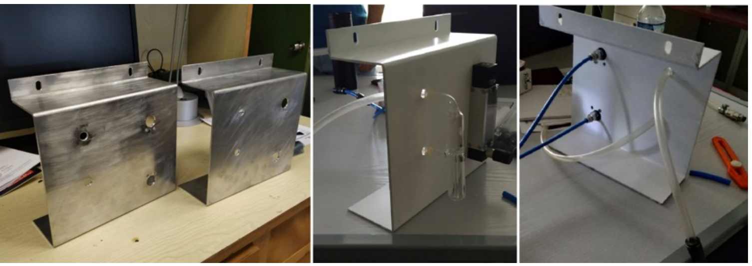


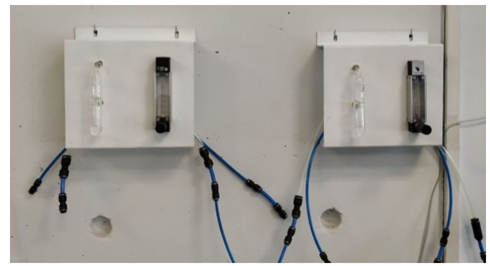


Work by the Practical students: Stamatis Tzanos, Vasilis Blanas

Build 2 Gas Flow Controllers

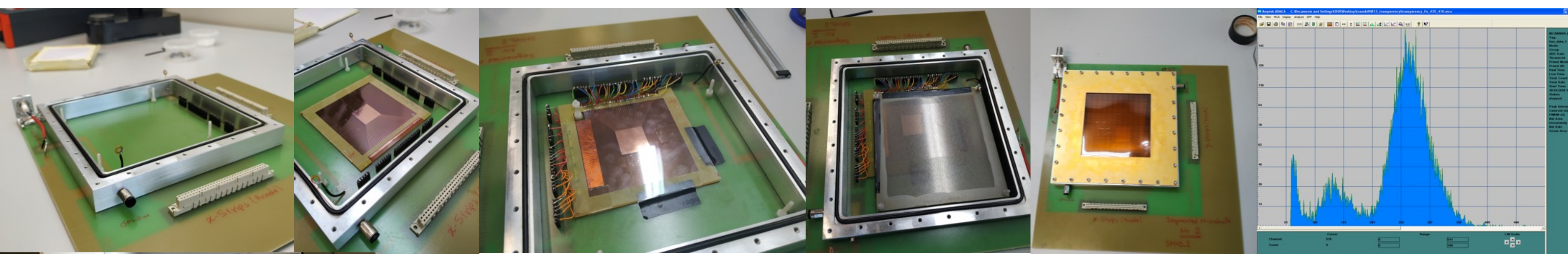






Excellent work
Done from A-Z

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

Backup

Demokritos responsibilities

Muon Software Coordinator (October 2021) (2 years term): George Stavropoulos
- It refers to all muon detectors in ATLAS.

sTGC Trigger Coordinator (January 2021): Theo Geralis

sTGC Trigger Commissioning in B191 and in ATLAS: Olga Zormpa
Key person for the Sectors - sTGC Trigger Commissioning
Olga got a Doctoral Studentship position at CERN

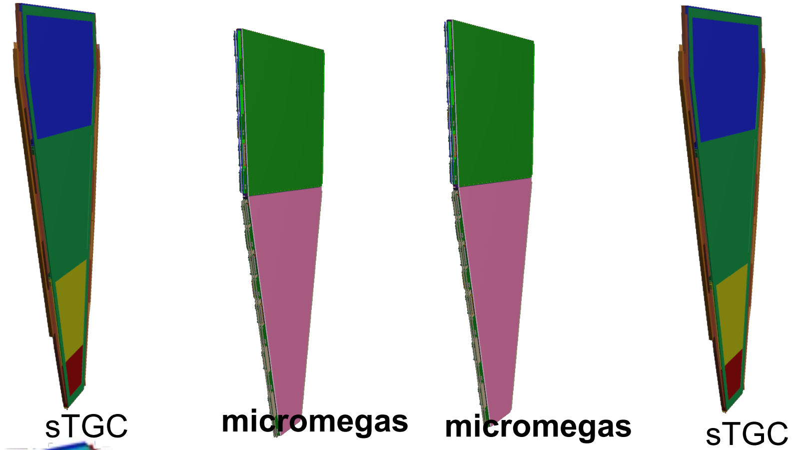
Physics Analysis with proton-proton collisions at the LHC

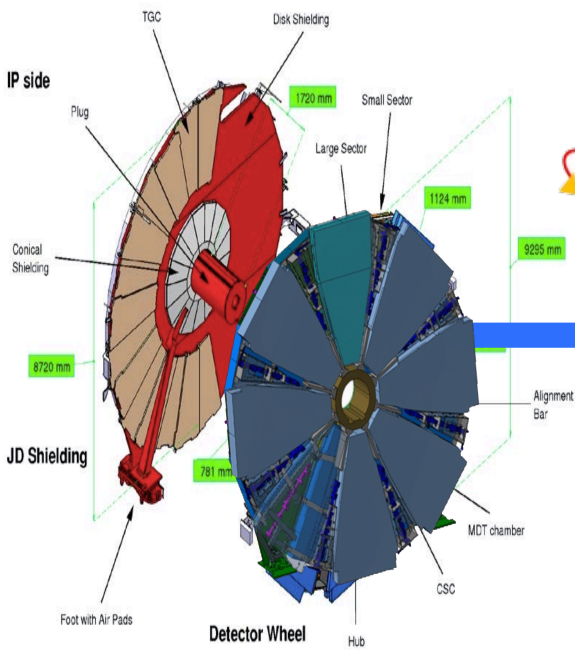
Technical work: Yannis Kiskiras
Key person on Technical matters at the sTGC integration site.

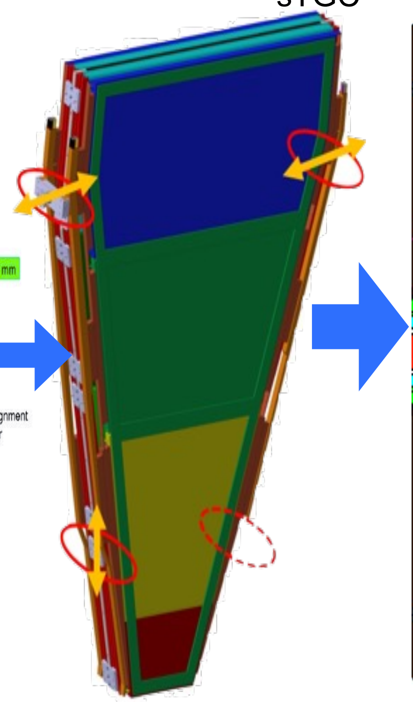
New Small Wheel (NSW) Layout

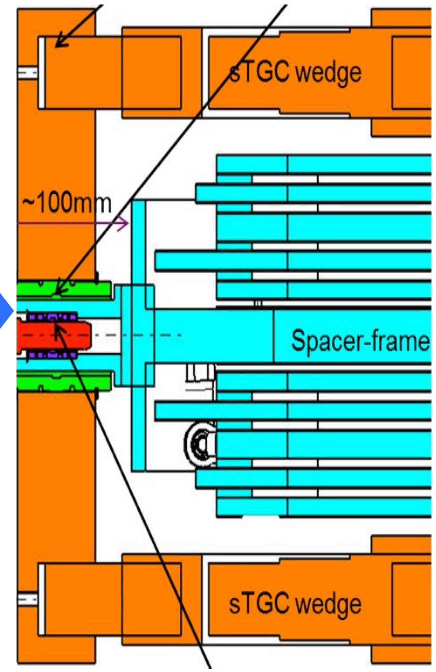
8 MM + 8 sTGC layers per NSW sector

- 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



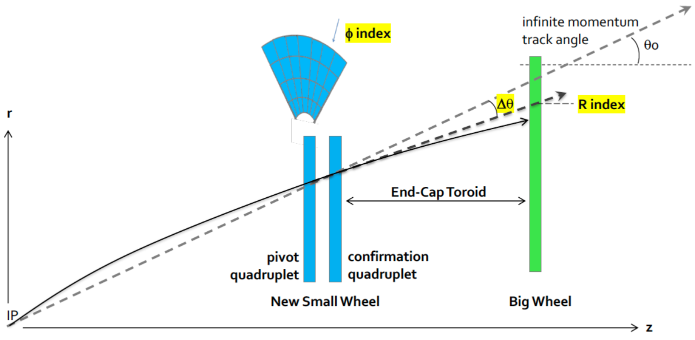


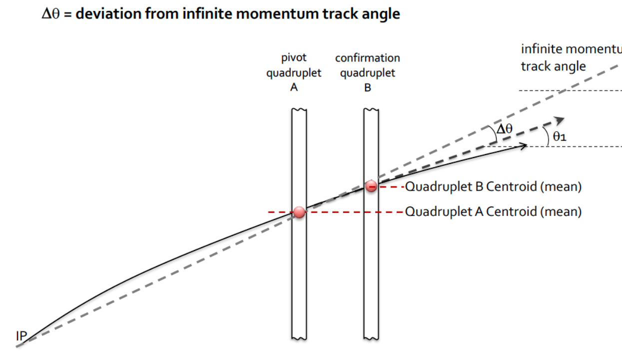


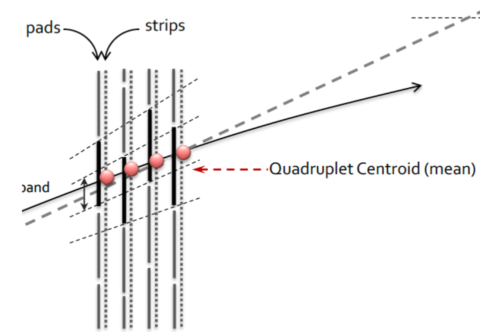


sTGC (mainly for triggering) & Micromegas (mainly for tracking) detectors, both providing tracking and triggering information, combined into a fully redundant NSW system!

NSW Triggering with sTGC





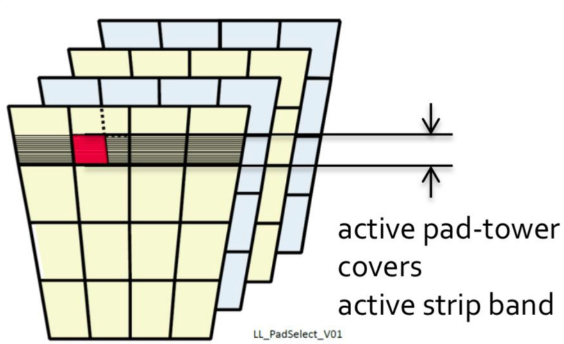


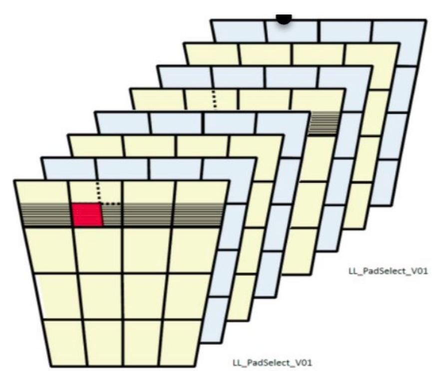
Combine BW + NSW: reduce fake rate

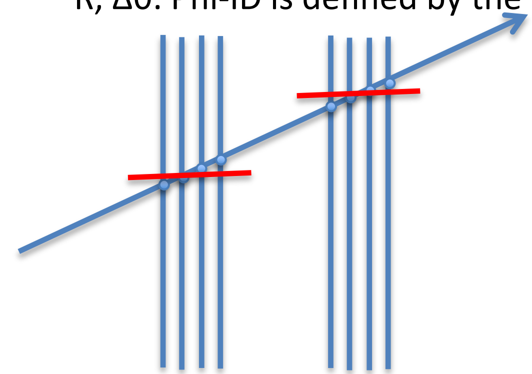
Pad Trigger: 3 / 4 AND 3 / 4 Coincidence
Select up to **4 Candidates (BandID, PhiID)**

Pad request: sTDS to Router to TP
Send Strips info for selected Bands

Trigger Processor: Define centroid of Strips charge per layer, compute R, Δθ. Phi-ID is defined by the pads







3 out of 4 to cover: 1) Detector inefficiencies
2) Tracks crossing only 3 pads

➔ To watch: effect of high background rates (γ, n) and pile-up hits.
On going studies: Gif++ data, Simulation

LVD6R REPEATERS COMMISSIONING

LVD6R production: Full production completed (PRISMA SA)

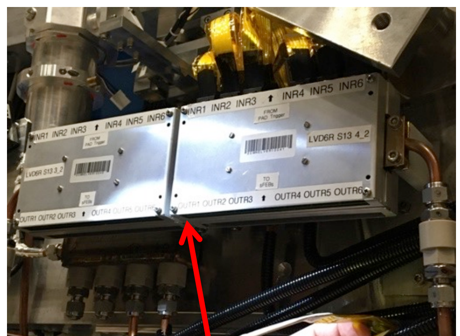
1st Batch: 70 LVD6Rs produced by middle of November 2019

2nd Batch: 70 LVD6Rs produced by end of February 2020

Shielding boxes: All 70 boxes built in Greece (Rentron)

LVD6R production completed: Wheel A (Feb. 2020) + Wheel C (Oct. 2020)

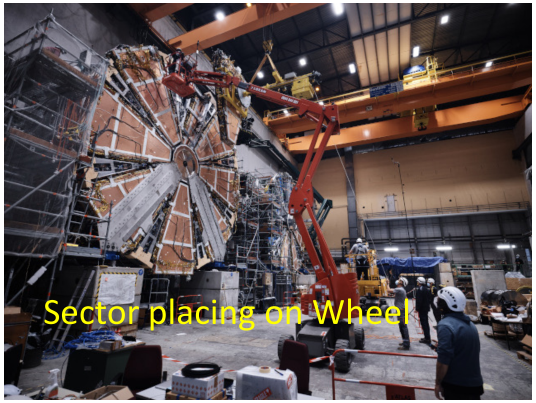
LVD6R bars for Wheel A



LVD6R mounted on Wheel A

Integration of all Repeaters, Serial and LVDS Was completed in September 2021 with the Completion of Wheel C

Integration of Sectors to form the Wheels



sTGC Trigger Slice system in B180

Build by the Demokritos group (Feb. 2020)

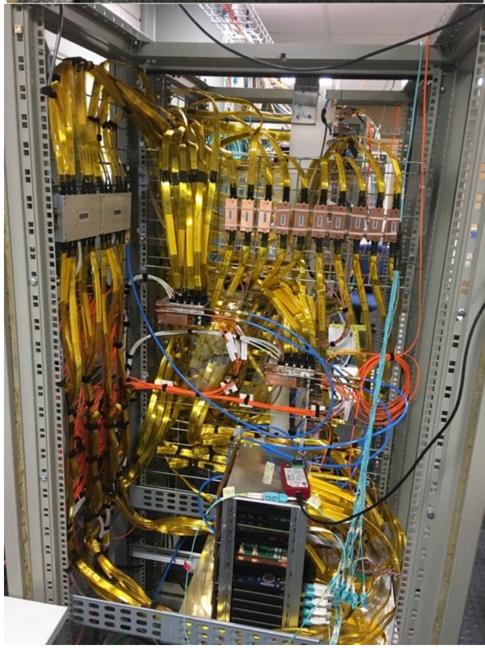
Purpose: Build complete autonomous Trigger Slice
➔ 1 Sector wedge

12 sFEB + 12 pFEB
Rim-Crate
- **1 Pad Trigger**
- **1 RimL1DDC**
- **4 Routers**

8 L1DDCs
2 LVD6Rs + 10 SRL1Rs
Trigger Processor
Felix

Connections as on the wheel for proper timings
Proper water cooling for all the components (I.Kiskiras)
The whole setup is hosted in two racks

➔ UNIQUE: ALL THE TRIGGER GROUP USED THIS SYSTEM REMOTELY
INTENSE USE DURING LOCKDOWN



Real x-y Segmented Mesh Microbulk Micromegas

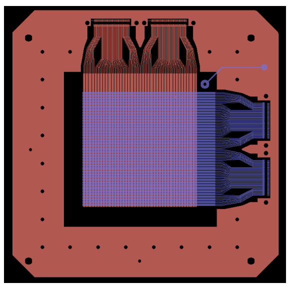
RD51 Common Fund Project (32.5 kCHF)

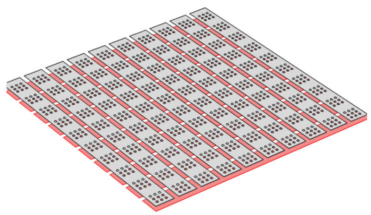
Collaborating groups:

NCSR Demokritos (Leading Institute) IRFU Saclay, Univ. of Zaragoza, CERN

Large detector

7cm x 7cm





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

Ideal for:

1) **Rare searches (axion, dark matter)**

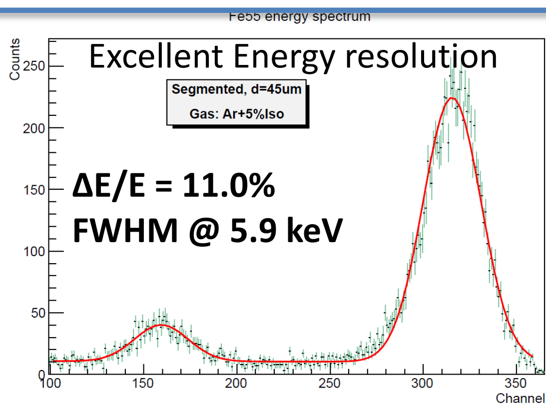
Background → ~ 10^{-7} cnts/keV/cm²/s

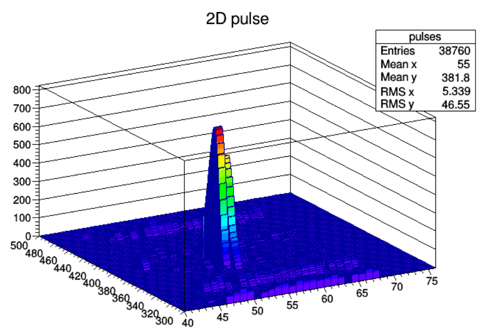
2) **Neutron Beam profiler (nTOF)**

Very low material Budget:

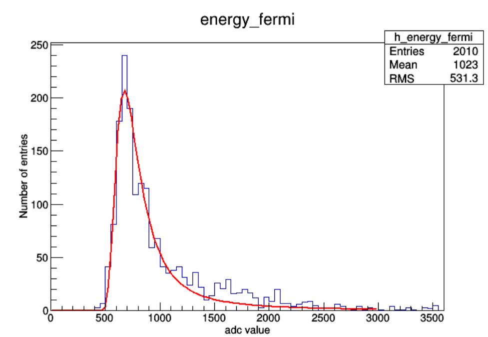
Real x-y microbulk with strip pitch 700 µm

Operation in TPC mode for tracking





Strip wave form → x,y,z coordinates

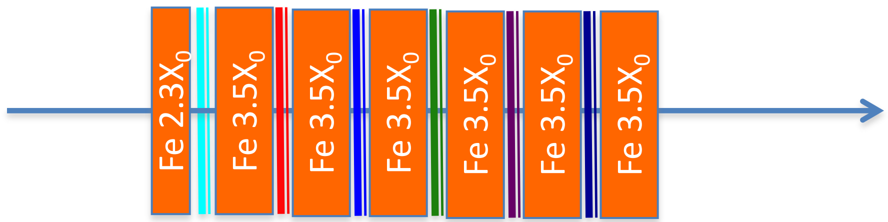


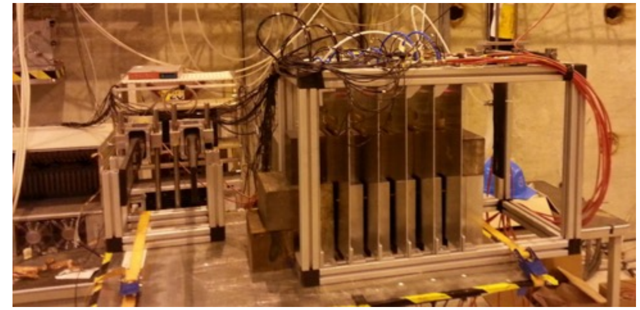
Landau distribution from Cosmic muons

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

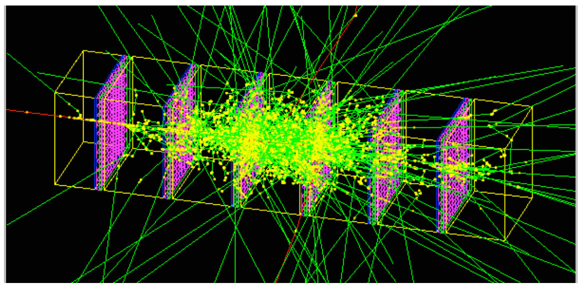
Build mini calorimeter with 6 res. uM and a total of ~20 $X_{0.}$ Test with electrons

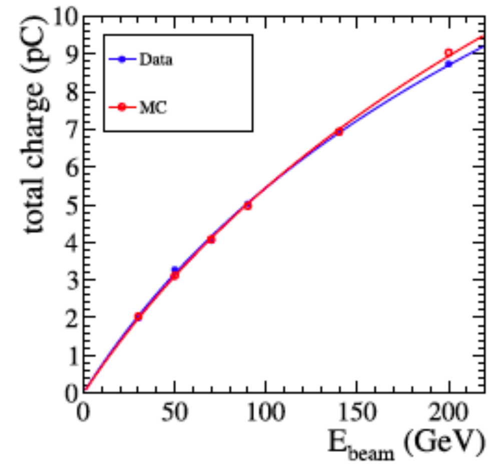
Electron Beam: 30, 50, 70, 90, 130, 200 GeV



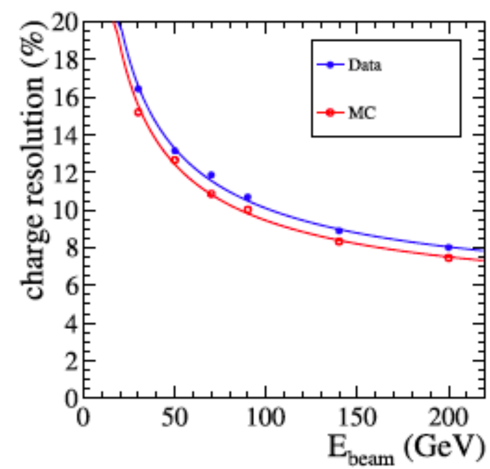


Simulated Events (Geant4): Exact geometry, 90 GeV shower





PROOVEN: Sparkless operation at high rates
Linear response at high rates ~100 MHz/cm^2
Large surface detectors, lower cost
Good candidate technology for future HCALs



Publications

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) *M. Chefdeville . Development of Micromegas detectors with resistive anode pads. NIM A 1003(2021) 165268*

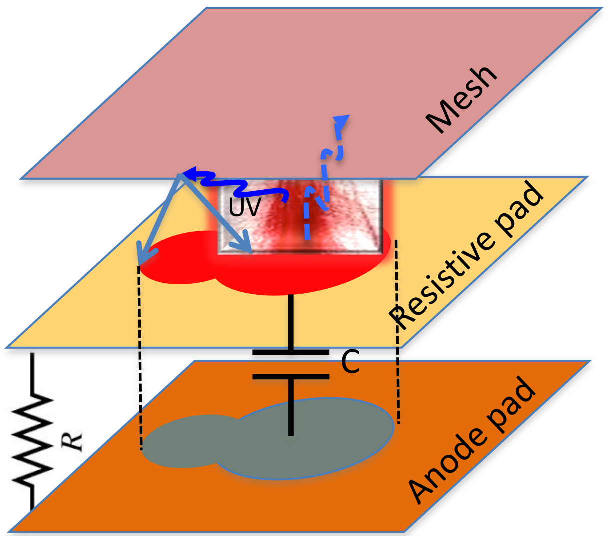
R&D Activities

Resistive Micromegas for High Rate Calormitetry

SCREAM: Sampling Calorimetry with Resistive Anode MPGDs

INPP, LAPP Annecy, CEA Saclay

Resistive layers prevent streamers to develop to sparks by quenching it at an early stage



R: Resistance to ground
C: Capacitance between resistive coating and ground:
f(cascade extend (~100 μm)) ~f(gas, drift length , HV, materials)

RC: gives typical time of the charge evacuation
High charge deposition deforms locally the E field → lower Gain
→ Quench spark → loss of linearity

τ : time of cascade development ~ 10 ns
RC > τ → Spark quenching
RC ~ τ → Spark develops
Our study: Vary RC (effectively vary R) and and study response linearity and discharge rate.

Charge evacuation:

- Sideways, horizontal evacuation of charge not adequate for large surfaces and high rates due to development of steady state charges
- Individual surface resistivity for every pad with buried resistor to ground, limits cross talk and cumulative effects of large surfaces (proposed by Rui De Oliveira)