MPGD-NEXT – TASK 3 :
HIGH PERFORMANCE MICROMEGAS

Congressino scientifico INFN - Roma TRE

September 13th, 2016

MicroPattern Gas Detectors (MPGD) are ideal tools for

1) fundamental research contributing to the excellence in science (f. i. : present and future large scale use in LHC experiments)

2) applications beyond science (better society)

In spite of the extremely relevant recent progress in the field, still a long way to go towards:

1) the ultimate limits of MPGD performance

2) simplified construction technologies to favour possible applications

in this context, in INFN :

Expertise in MPGDs (ATLAS, CMS, COMPASS, LHCb, KLOE2, TOTEM, …)

dedicated infrastructures (constructions for the exp.s)

MPGD-NEXT - PROJECT

- **3-year project 2016-2018**
- **PI: S. Dalla Torre, INFN TS**
- **5 INFN UNITS, (28 + 3) participants, ~8 FTE**

DEVELOPMENT of Novel MPGD architectures

Technical complements

TASK	TITLE	TASK RESPONSIBLE	CONTRIBUTING INFN UNITS	NON INFN PARTICIPANTS
1	The Resistive-WELL detector (R-WELL)	G. Bencivenni	LNF	
2	Fully resistive pattern detectors	M. Maggi	BA	CERN
3	High performance MICROMEGAS	M.Iodice	RM3, NA	
4	High-gain hybrid MPGD	F. Tessarotto	TS	
5	FE developments for high space and time resolution MPGD	A. Ranieri	BA, LNF	
6	MPGD-dedicated HV system	S. Levorato	TS	

Roma Tre Unit: M.Biglietti, M.Iodice, F.Petrucci

In Collaboration with Paolo Iengo (CERN)

With the great help of S.Franchino and the RD51 group

Task-3 budget quite small: ~10kE in 2016

MPGD-NEXT – Task 3 : High Performance Micromegas

Goal:

Development of improved Resistive MicroMegas (MM) detectors with small pad read-out, aimed at improving the high rate capability. Aim at ~1 MHz/cm^2

→ Small Pads Resistive MM

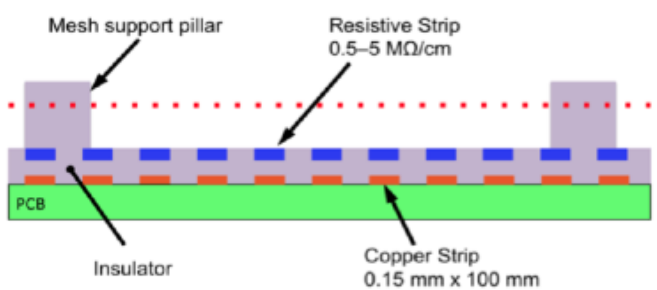
Applications:

- Large area fine tracking and trigger with high rate capability (one possible application: ATLAS very forward extension of muon tracking
- Sampling Hadron Calorimetry

"Past R&D / Present Status" -- Resistive Micromegas:

Now a mature technology for HEP experiments also taking advantage of the intense phase of R&D for the ATLAS Experiment were resistive MM will be employed in the upgrade of the Muon Spectrometer (**New Small Wheel**) :

- Large area: total surface of ~1200 m2 of gas volumes
- Operation at moderate hit rate up to ~15 kHz/cm2 during the phase of High-Luminosity-LHC



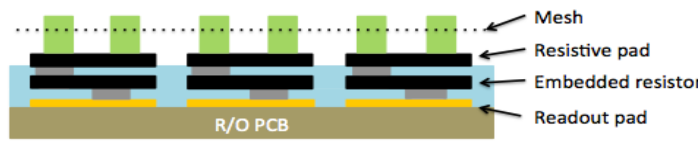
NEXT: Small Pads Resistive Micromegas:

Small Pad pattern with EMBEDDED resistors.

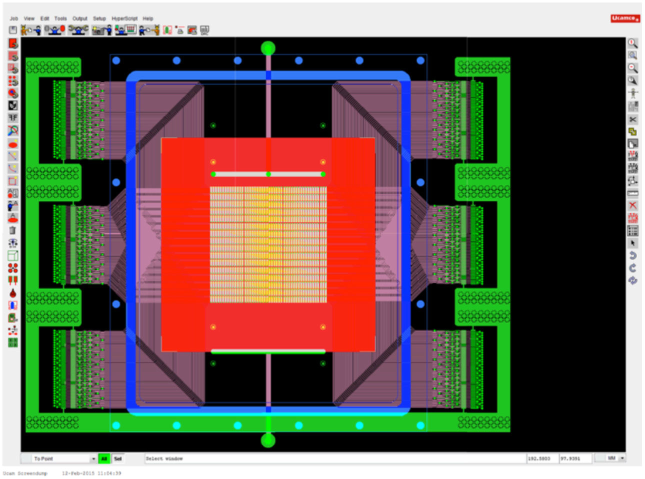
Technical solution inspired by a similar R&D by COMPASS.

We aim at reducing the pad size from ~1cm2 to <3mm2

The construction technique depends on the pad-size



NEW CONSTRUCTION TECHNIQUE (Rui De Oliveira) with a stack of all layers all deposited by screen-printing



- First design of a small size prototype
- Matrix of 48x16 pads
- Each 0.8mm x 2.8mm (pitch of 1 and 3 mm in the two coordinates);
- A total of 768 channels

PROJECT TIMELINE (AS PRESENTED IN SEPTEMBER 2015)

In a three year R&D project we aim to:

✔ 1. Optimize the design of resistive micromegas with small size pad readout; **[succesful]**

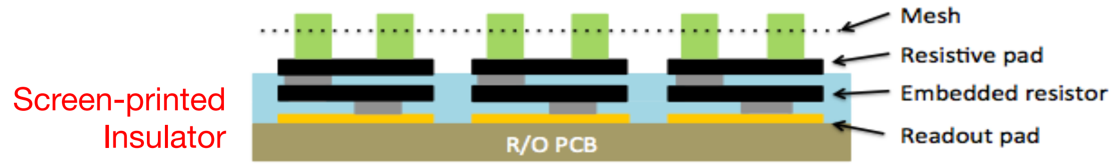
✔ 2. Optimize the construction;

3. Optimize the parameter of construction (resistivity,…) and operations (gas mixture,…); **[Two prototypes built. Ongoing – Very good progress]**
4. Establish the optimal trade-off between dimensions and channel routing to read-out electronics;
5. Establish safe operation up to a rate of O(1MHz/cm^2);
6. Achieve good spatial and temporal resolutions (~100 μm and few ns respectively);
7. Start a process of technology transfer to industries.

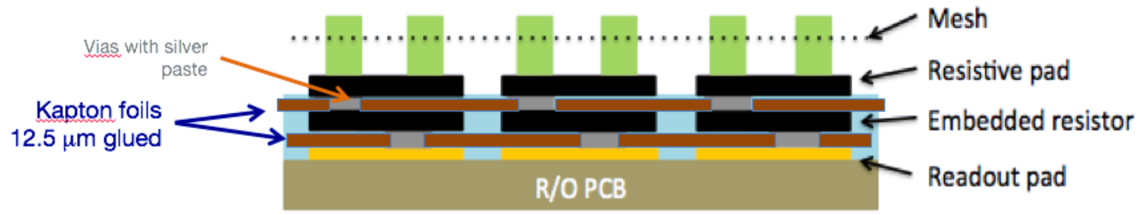
TWO Prototypes built so far (Paddy1 and Paddy2)

- Both with the same layout: Matrix 48x16 – 1x3 mm^2 pads – 768 channels
- The construction technique was different in the two cases

1. Full screen printing: stack of all layers, including the insulator, all deposited by screen-printing (new technique by R. De Oliveira and A. Teixeira). A simple, cost effective technique but subject to HV instabilities



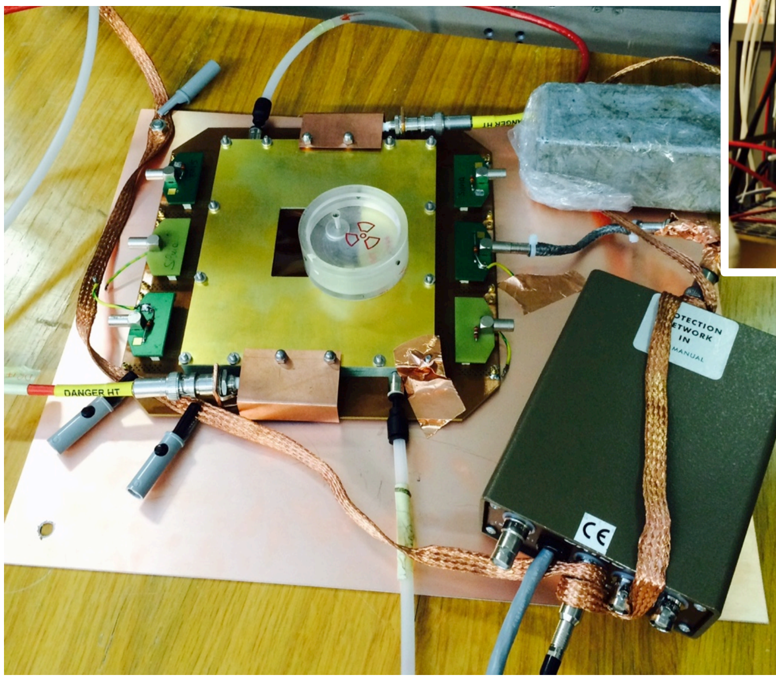
2. “standard kapton insulating foils”. Tested without any problem of HV instabilities.

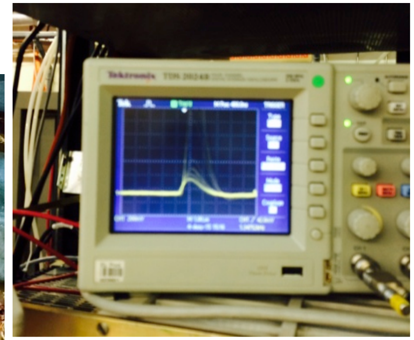


In the pressing procedure the resistivity increases
→ used “low resistivity” paste 100 kΩ/sq

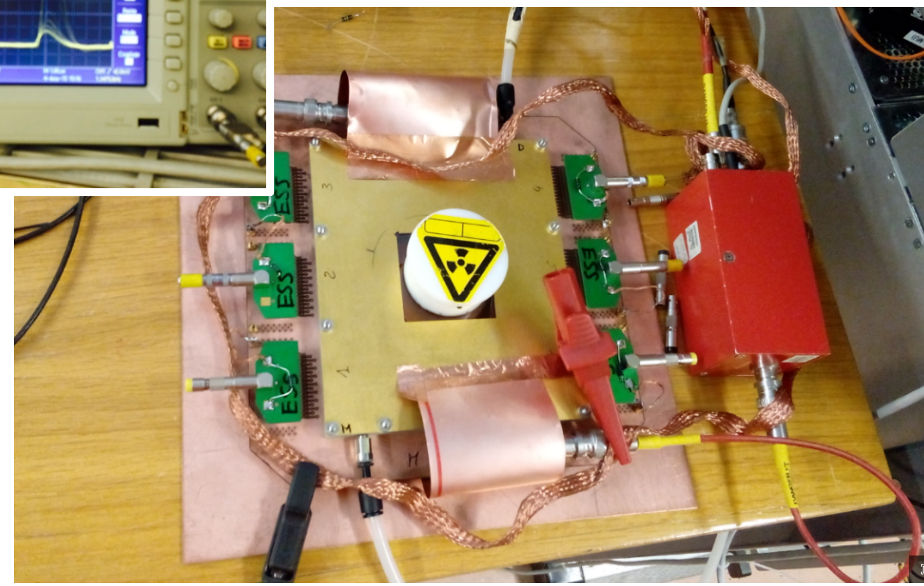
Lab Tests

Paddy1 – Tests in late 2015





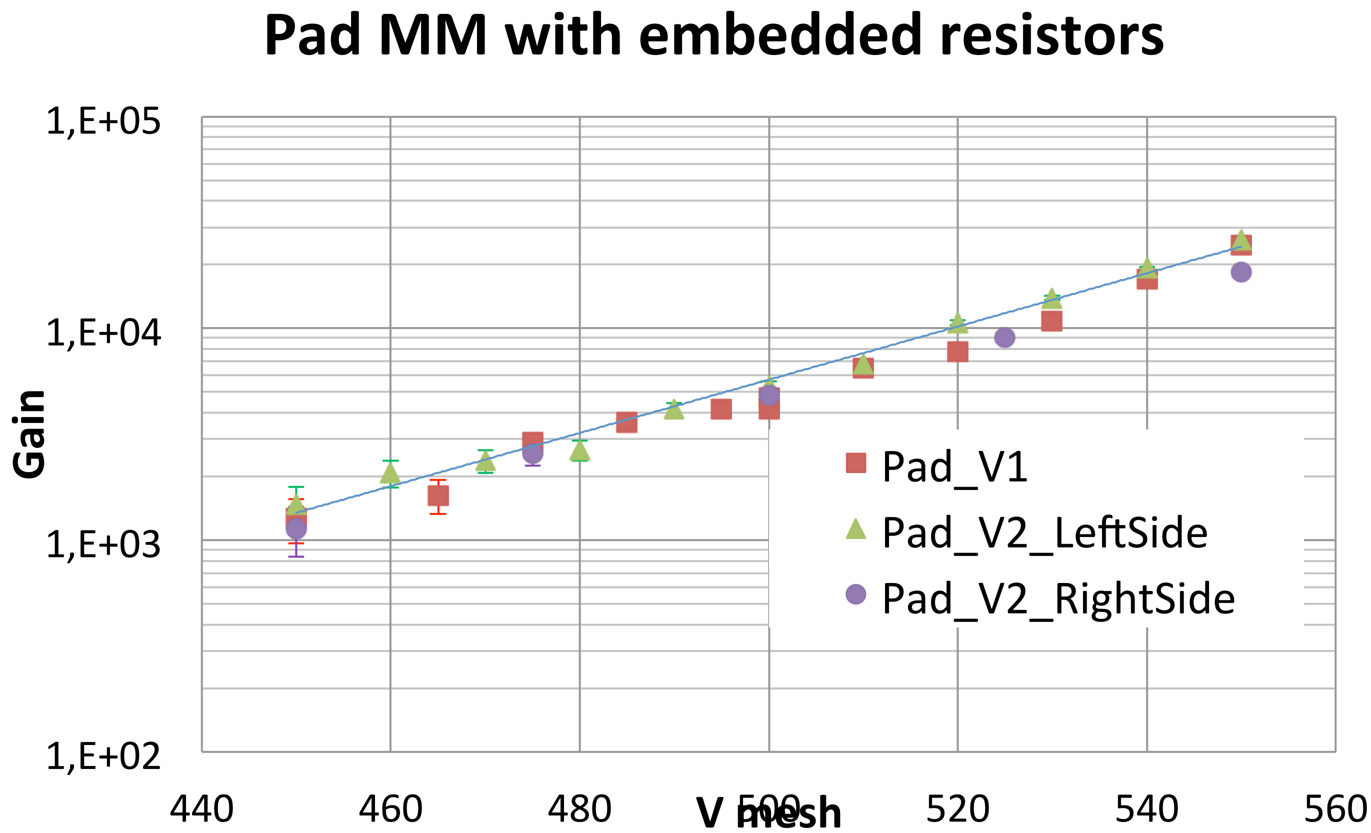
Paddy2 – Tests in July 2016



GAIN CURVES:

- Taken from Current on the mesh Imon Power supply (to correct only by IBF, usually few % in a micromegas)
- Rate from oscilloscope
- N prim in Argon with Fe55 ~ 200
- G = Imon/(q*Nprim*rate @ plateau)

Gain Results



- Compatible with bulk micromegas
- OTHER TESTS AND RESULTS NOT REPORTED HERE

PROJECT TIMELINE

In a three year R&D project we aim to:

✔ 1. Optimize the design of resistive micromegas with small size pad readout; [successful]

✔ 2. Optimize the construction; [Two prototypes built. Ongoing – Very good progress]

2017

3. Optimize the parameter of construction **(resistivity**,…) and operations (gas mixture,…);

4. **Establish the optimal trade-off between dimensions and channel routing to read-out electronics;**

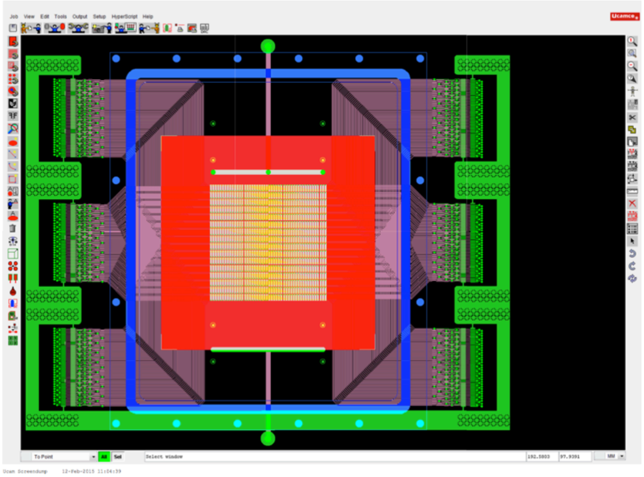
5. Establish safe operation up to a rate of O(1MHz/cm^2)

6. Achieve good spatial and temporal resolutions (~100 μm and few ns respectively);

7. Start a process of technology transfer to industries.

NEXT (MAJOR) STEP: READOUT FOR "LARGE" DIMENSIONS

- **Establish the optimal trade-off between dimensions and channel routing to read-out electronics;**



The present layout IS NOT scalable for large dimensions

FRONT-END …towards LARGE DIMENSIONS

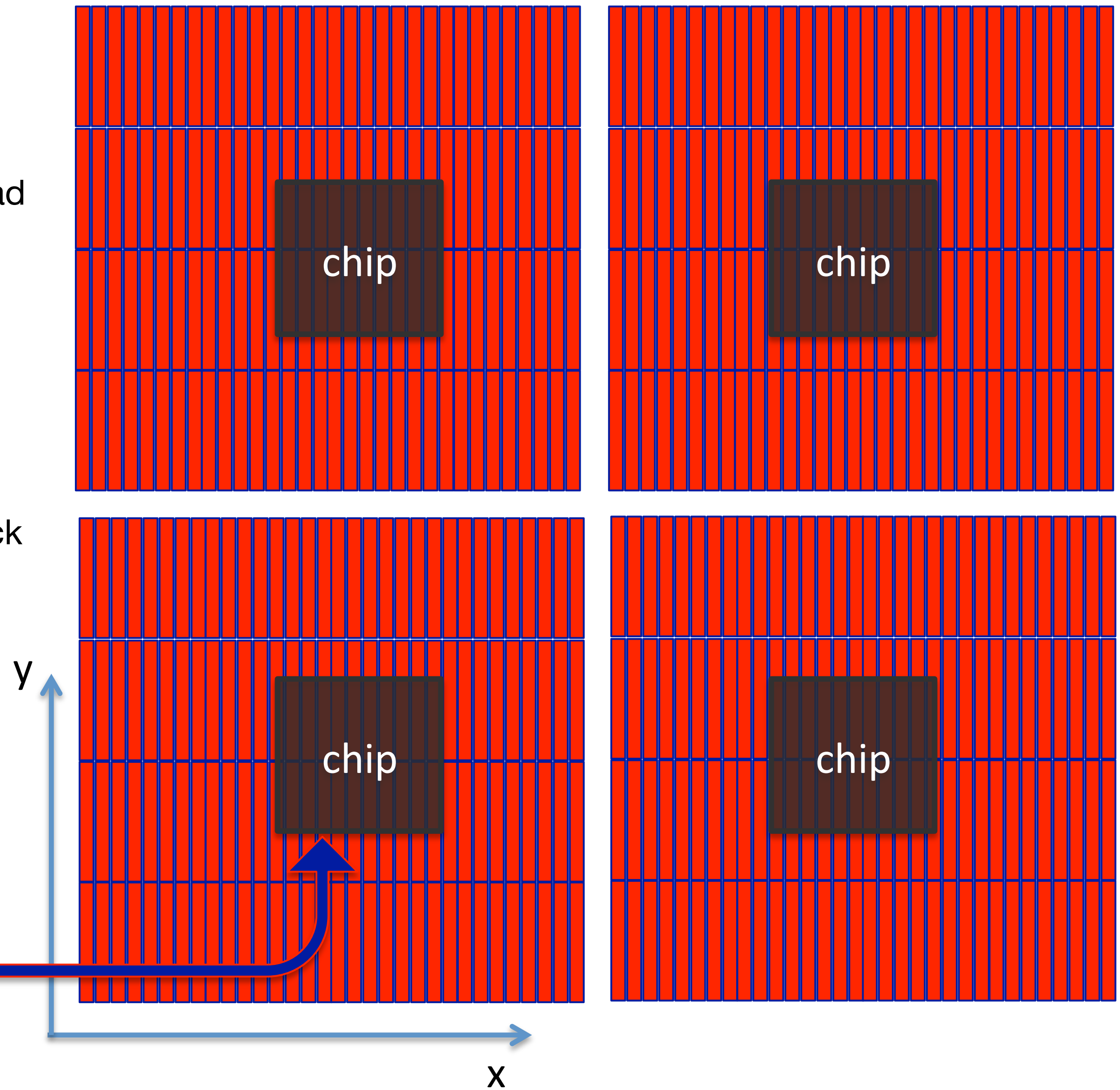
- LAYOUT IS NOT SCALABLE FOR LARGE AREA
- Very difficult routing off detector planes
- Routing through flex? Difficult in case of limited space and/or multilayer detectors
- BEST OPTION: Wire-bonded chips on the back of the detector readout boards

Back wire bonded chip and Front-End Components

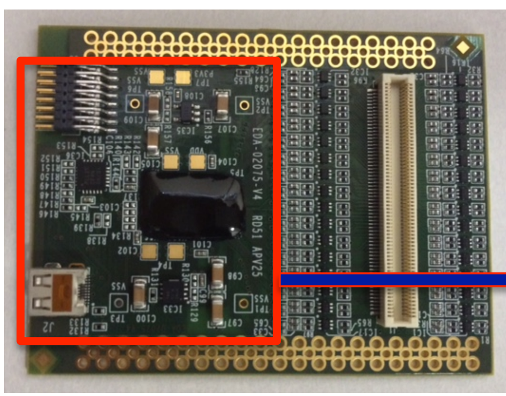
A realistic implementation

LAYOUT VERSION v0

- Divide in 4 regions with 32x4 mini-pad
- Pitch x: 1 mm
- Pitch y: 8 mm
- Each pad is 0.8 mm x 7.8 mm
- Space between pads is 0.2 mm
- Each region is 32x32 mm2
- Each region can be readout by a back wire bonded APV25 chip with associated Front-end electronic reassembled on the detector board



APV25 Hybrid by RD51

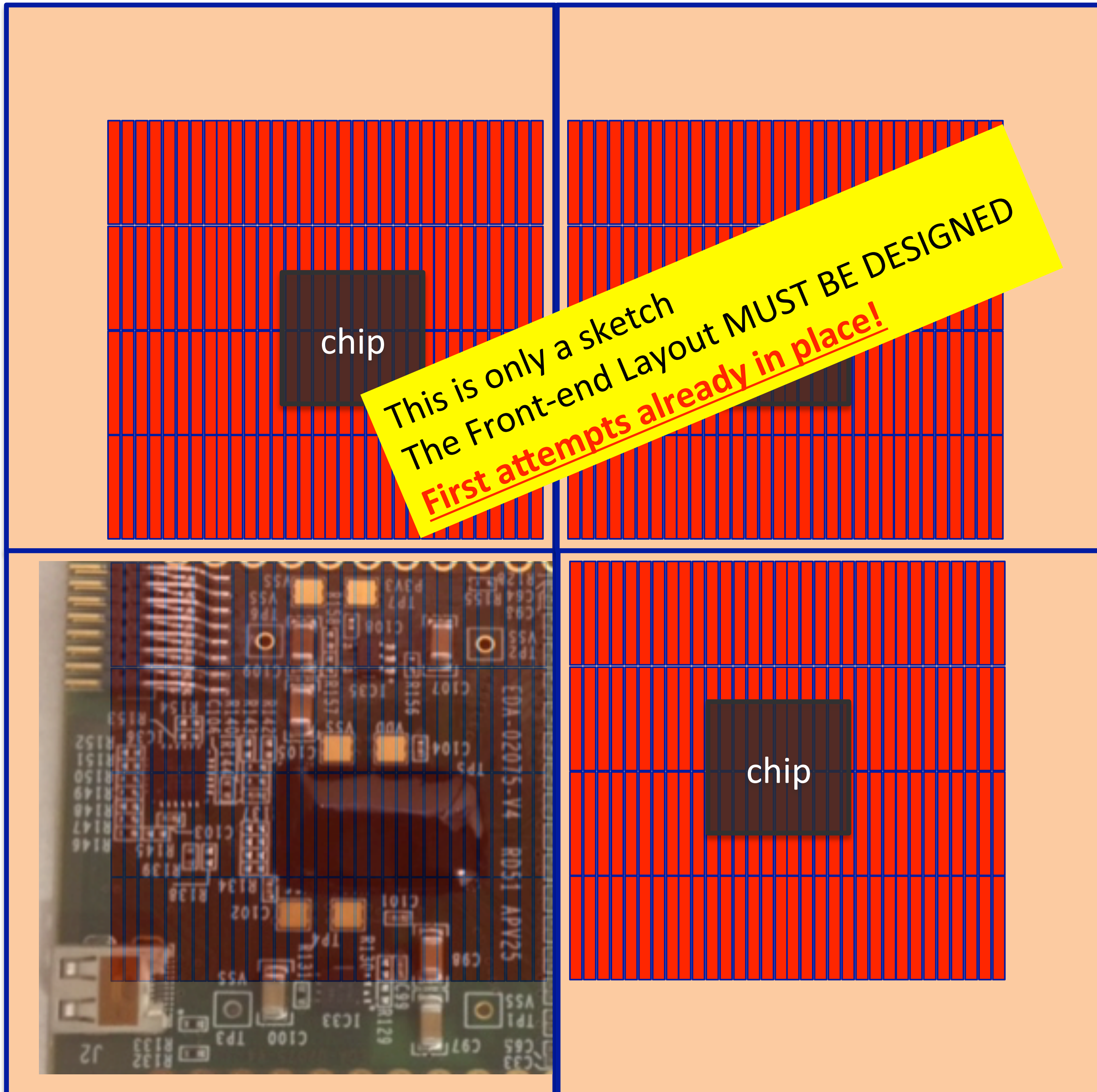


LAYOUT VERSION v0

- 4 regions 32x4 mini-pad
- **For the present development the area available for the Front-end, including mini-HDMI connectors, can be larger.**
  For example up to 40x40 mm2
  (IF NEEDED)

Final detector
4 regions

- 4x (32x32)mm2 active area
- Up to 4x(40x40)mm2 Front-end surface
- 4 “master-like” APV hybrids
- 4 μHDMI connectors



PROGRAM 2017

1. Performance with the second small size prototype (Paddy2) with cosmic rays, test beam and under high irradiation

2. **Design and Construction of MM with Embedded Readout Electronics**

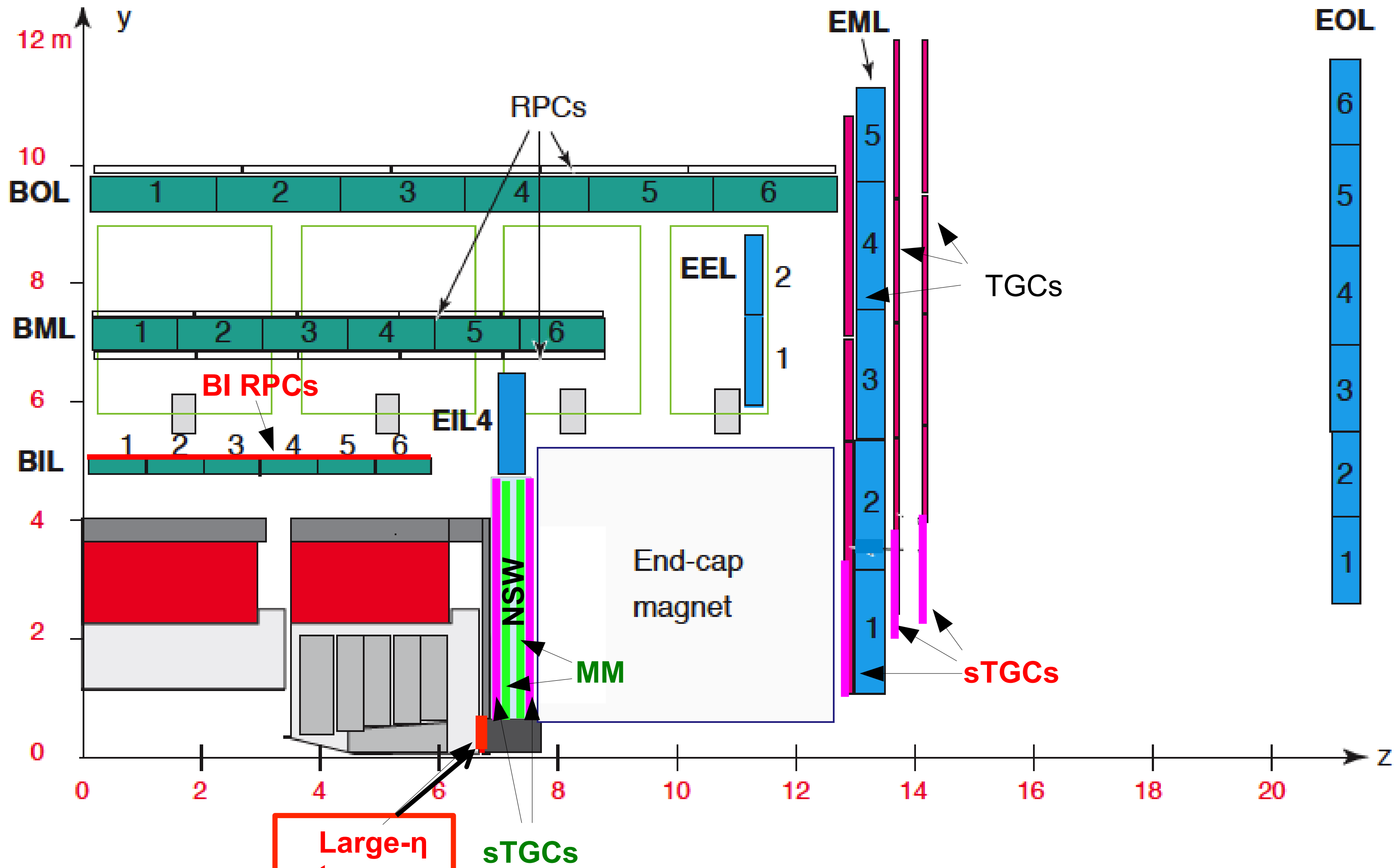
MILESTONE !

3. Design and construction of a new small size small-pads prototype for resistivity optimization studies (a configuration different from the "embedded resistor" is also under study).

FIRST TIME A MPGD DETECTOR WITH EMBEDDED READOUT ELECTRONICS WILL EVER BE PRODUCED !!!

A CHALLENGING, FUNDAMENTAL STEP THAT CAN OPEN NEW SCENARIOS FOR HIGH GRANULARITY – HIGH RATES DETECTION !!!

ATLAS Phase-2 muon scenario with Large η muon tagger



Large-η tagger
Z~6800

Extend the tag-muon acceptance up to η ~ 4

ATLAS LARGE η MUON TAGGER

- ATLAS Large eta upgrade Task Force established in 2015. Results documented in: ATL-UPGRADE-INT-2015-001
  https://cds.cern.ch/record/2020591?ln=en

- A Muon tagger is present in the Scoping Document for the "reference scenario":
  - The planned extension of the ATLAS inner tracker to pseudo-rapidities between 2.5 and 4.0 makes it interesting to identify muons in this large pseudo-rapidity interval.
  - For the interval 2.7< |η| <4.0 we propose to instrument the region between the end-cap calorimeter and the JD shielding disc with position sensitive detectors to allow the tagging of inner detector tracks as muons
  - Detector: ~5 planes, high granularity, Silicon or Micro-Pattern Gaseous detector

<u>Requirements:</u>

- Reconstruct a muon segment after the calorimeter
- Matching with a ITK track (position, angle)
- Operation at ~10 MHz/cm2 at R=25 cm
  - Position resolution: few 100 μm
  - Angle resolution ~ 10 mrad
  - Requirements (greatly) relaxed at large R

DETECTOR CHOICE

Detector Technologies considered so far :

- Pixel detector at small R
- Strip readout also OK at large R (length, from which R ..?)

Also considered and proposed for the first time at the last Muon Week (June, 9th)
https://indico.cern.ch/event/539175/

- Micro-Pattern Gaseous Detectors.
- Using the resistive anode technology developed for NSW MM.
  (Si pixel detector satisfies the requirements, but too expensive)
  - MM with mini-pad / pixel readout (CERN, INFN, Mainz)
  - Resistive Well (Bencivenni's type detector) (USTC)
  - Resistive micro-PIC (JAPAN) (not yet a solid technology – more R&D needed)

Expression of interest by INFN: Na, Pv, Rm3 + Le, Rm1

1. R&D on improved Resistive MicroMegas detectors with small pads

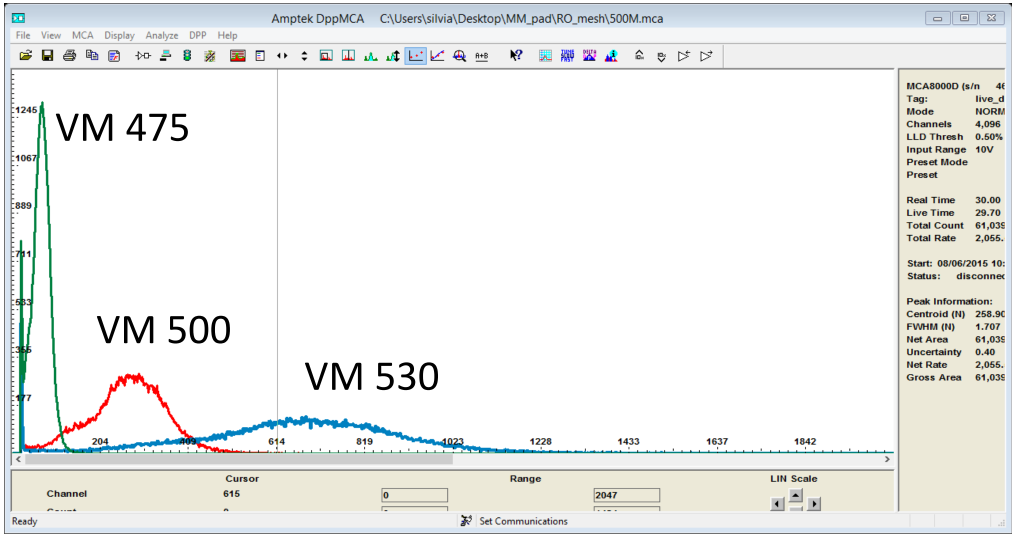
2. Development of NEW MPGD with "embedded electronics" (back bonded readout chips)

- Work started already in the context of MPGD-NEXT (CSN5) (INFN Rm3, Na)
- In collaboration with CERN (P. Iengo)
- And with the CERN PCB Workshop (Rui De Olivera) for prototype construction

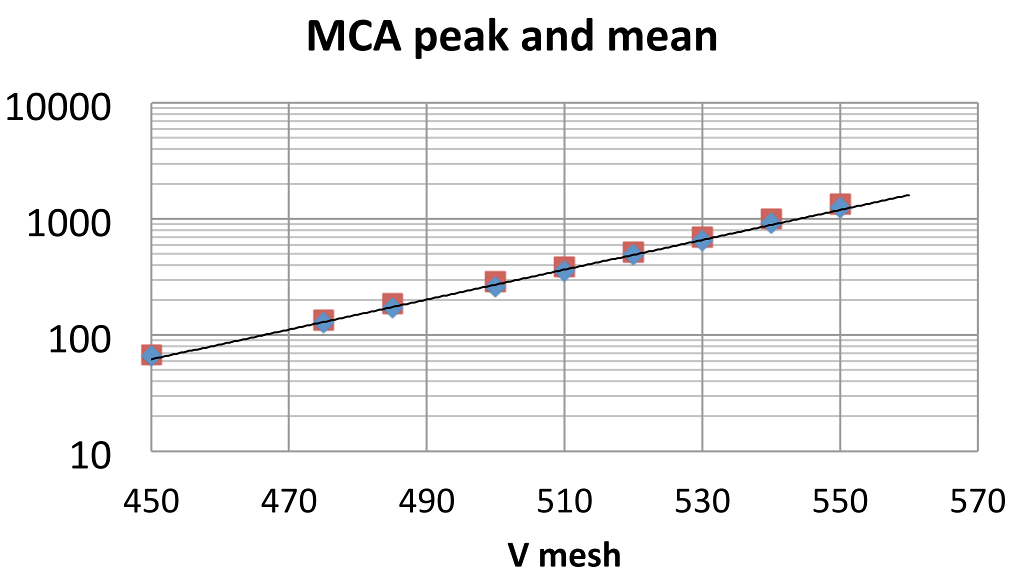
- …and many other fields where we can (and want) contribute (simulations, physics case, validation of background, in situ tests, ...

Backup

PADDY1: READING WITH MCA



RO from mesh
Pads GND
Voltage on mesh
V d = Vm + 300



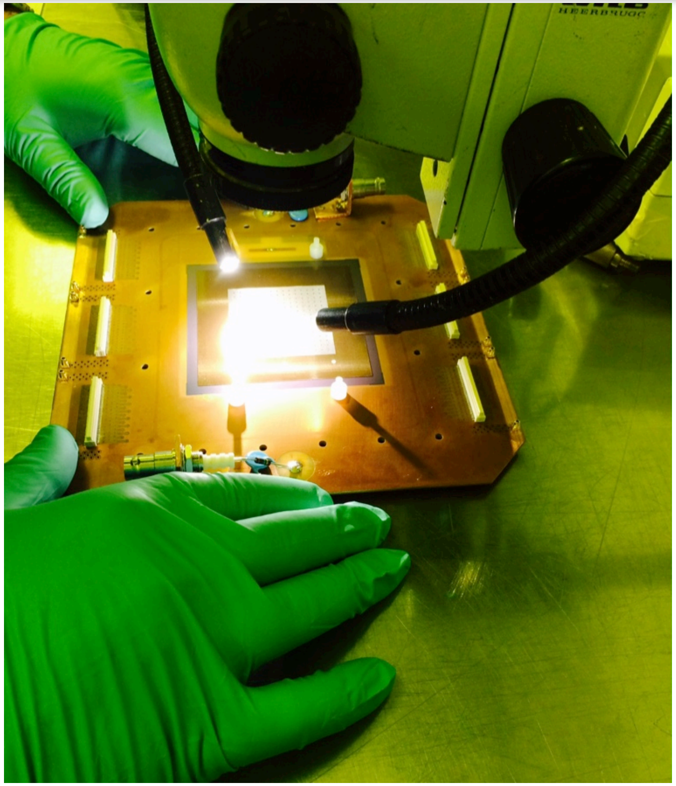
Not great Energy resolution

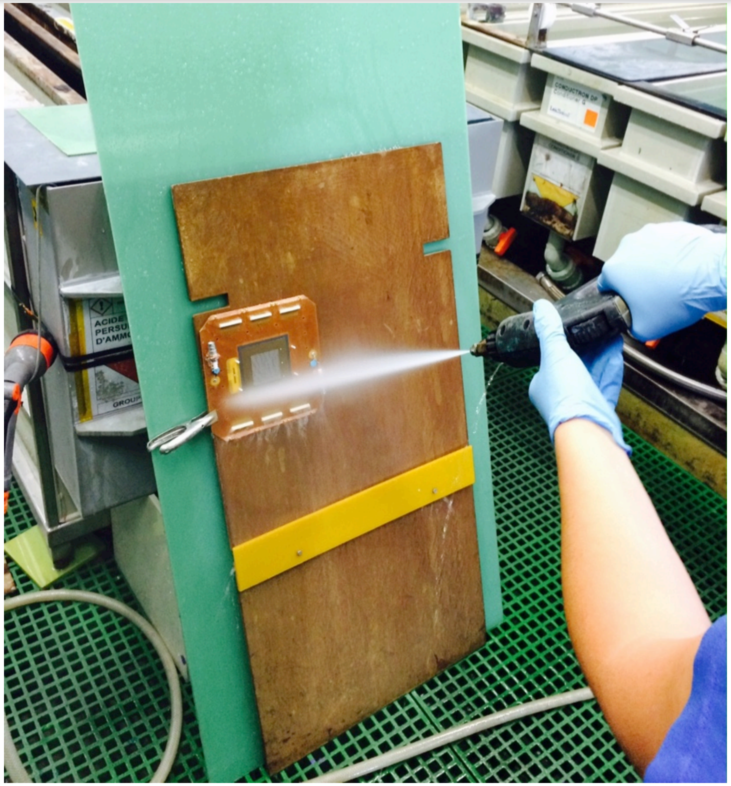
According to Antonio Teixeira and the trials of Max Chefdeville it's due to border effects on each pads from the screen printing process:

not flat pads → not uniform E_field

In this case small pads → a lot of borders

PADDY1: READING WITH MCA





Careful inspection, Cleaning: only temporary fix …not able to operate the detector

- Discussing with Rui we concluded that there might be issues with the “full screen printing” technique. In particular:
    - Pin-holes / weak points in the insulator
    - Shape of the resistive pads not flat. Bumps and irregularities

→ DECIDED TO BUILD A NEW PROTOTYPE WITH Kapton as insulator →

PRODUCTION OF ONE DETECTOR WITH EMBEDDED ELECTRONICS COST

Production of one detector with embedded electronics by Rui De Olivera:

Layout:	4000 CHF
resistive layers + BULK	4000
8 layer PCB	2000
Component assembly	1000
Mechanics	1000
TOT	12 kCHF (subject to variations up to +/- 20 %)

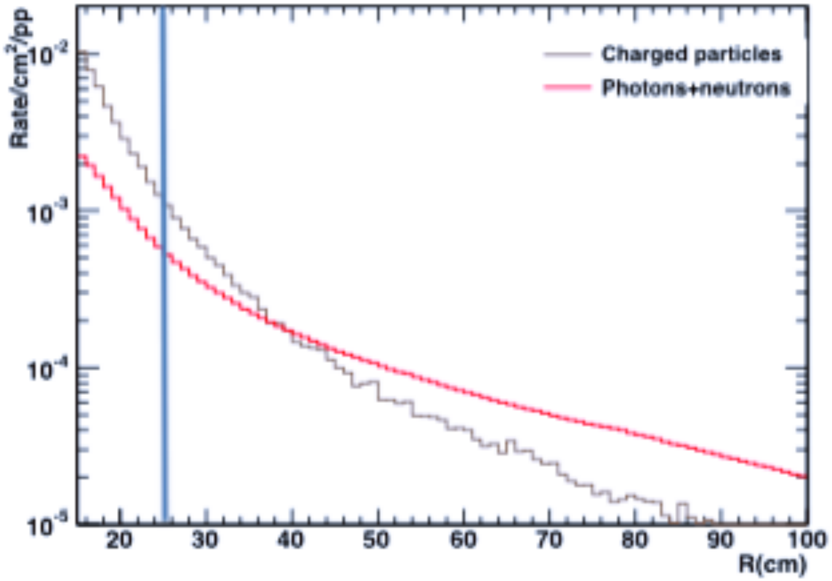
FIRST TIME A MPGD DETECTOR WITH EMBEDDED READOUT ELECTRONICS WILL EVER BE PRODUCED !!!

A CHALLENGING, FUNDAMENTAL STEP THAT CAN OPEN NEW SCENARIOS FOR HIGH GRANULARITY – HIGH RATES DETECTION !!!

HIT RATES

Hit rate

Hit rate per cm^2
For each pp collision



Assuming
n, γ sensitivity = 1%

At R = 25 cm (η=4.0), rate is ~ 9 MHz/cm^2 for μ = 200

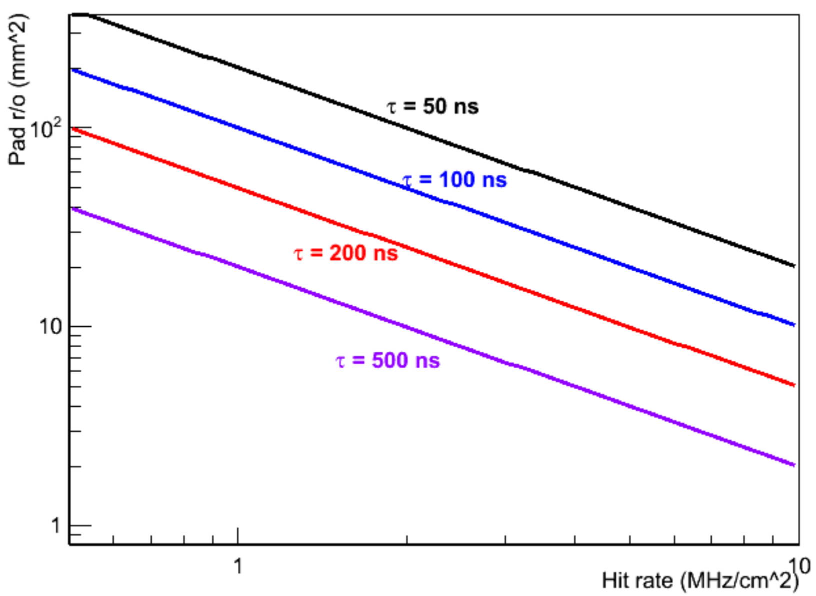
- APPROXIMATELY we have the following rates at the different radii :

25 – 37 cm	10MHz - 2 MHz
37 – 59 cm	2 MHz - 400 kHz
59 - 97 cm	400 kHz — 70 kHz

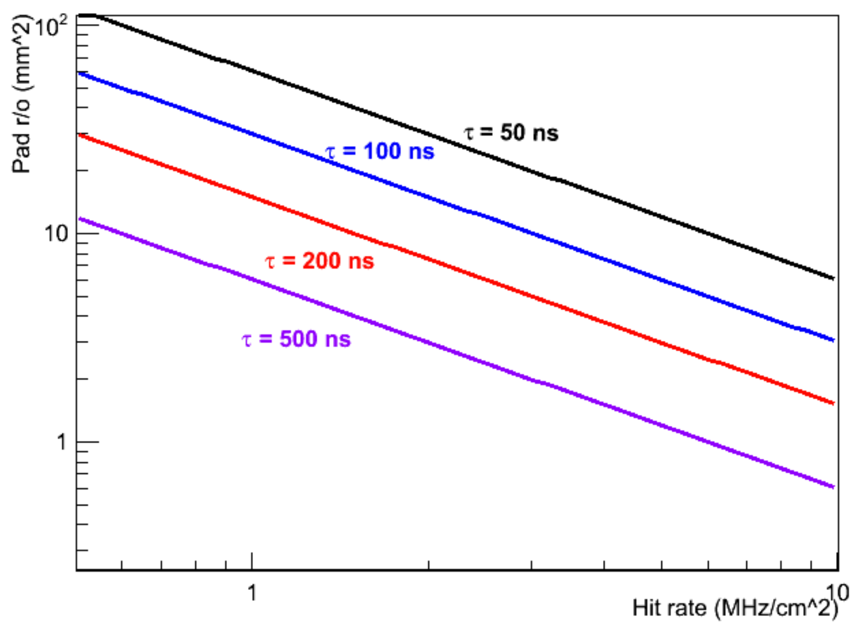
Occupancies Vs Hit rates

Dimension of the pad readout (either strips or pads) as a function of the hit rate for an occupancy level of 10% (left) which is kind of the maximum acceptable and 3% (right) which is a “comfortable number.
Each line is for a different pulse width (or charge collection time).

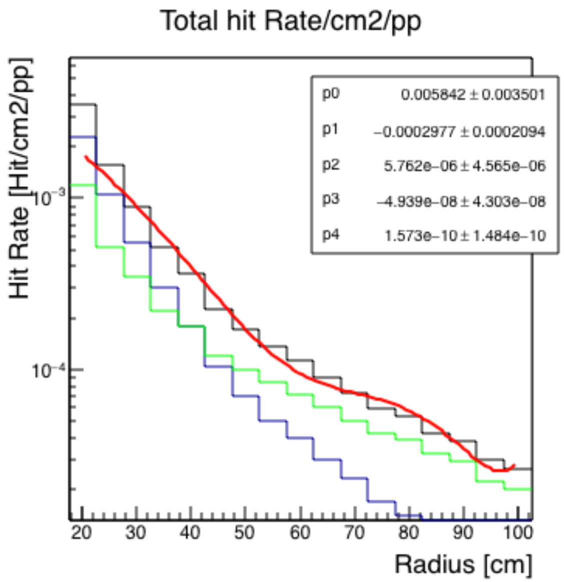
occupancy level of 10%

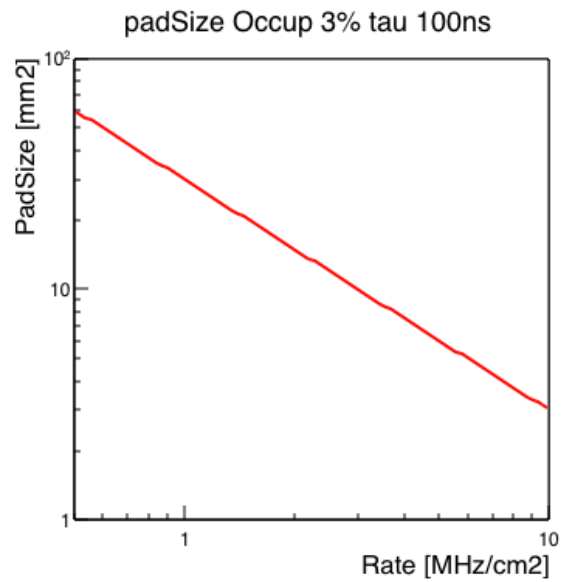


occupancy level of 3%



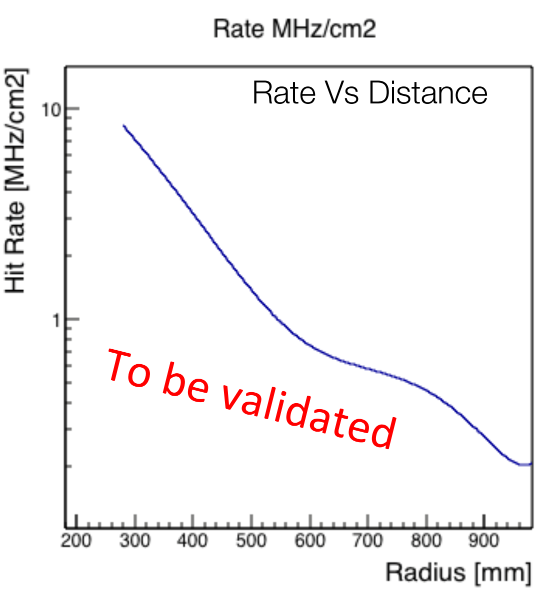
NUMBER OF CHANNELS – "CONTINUOUS SCALING OF PADS"

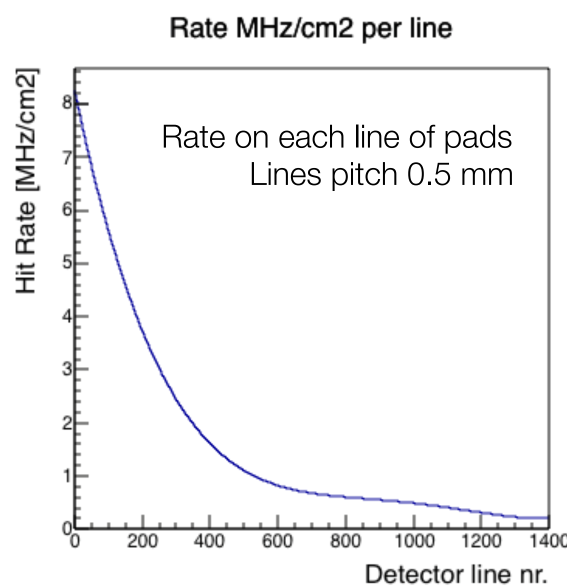


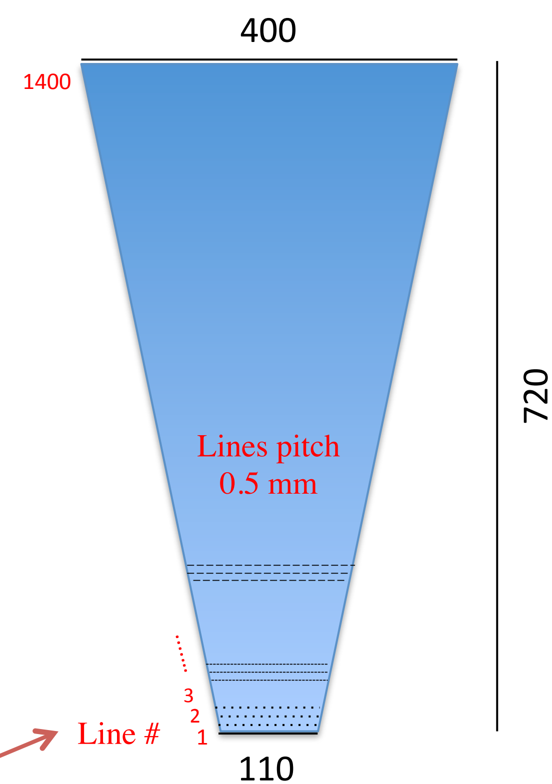


Pads → "ministrips" along lines with constant spacing → pitch 0.5 mm

Very short at small R – much longer at large R







UPDATE OF THE PROJECT PROFILE

&

ASSEGNAZIONI 2016 E PREVENTIVI 2017

ACTIVITY PROFILE - UPDATE

GANTT CHART as of July 2015

activity	2016				2017				2018			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Simulation and Design of MM with pixelated anode												
Construction and tests of the first small prototype (10x10 cm2)												
Design of second generation small prototype												
Construction and test of second generation small prototype												
Construction of large size prototype (~40x40 cm2) and cosmics tests												
Test-beam and High Irradiation Tests												

GANTT CHART as of July 2016 -- REVISED

activity	2016				2017				2018			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Simulation and Design of MM with pixelated anode												
Construction and tests of the first small prototype (10x10 cm2)												
Construction and TESTS of an improved small size prototype												
Design, construction and test of second generation small prototype (new Resistive Layout												
Design and Construction of MM with EMBEDDED ELECTRONICS for Large Size Detectors												
Construction of large size prototype (~40x40 cm2) and cosmics tests												
Test-beam and High Irradiation Tests												

Updates from the original planning:

- The first MM mini-pad Prototype has shown some limitations. A second small size prototype with a different construction technique has been built in 2016 and currently under tests. First data ARE VERY PROMISING !

- We already started to investigate a scalable solution for the Front-End Readout. One more step in the R&D is needed.
  THIS IS A very exciting and challenging STEP !

SITUAZIONE 2016 E RICHIESTE 2017

TASK 3			INFN unit NA			INFN unit Roma3		
			2016 Rich.	2016 Ass.	2017 Rich.	2016 Rich.	2016 Ass.	2017 Rich.
	Consumables	Resistive MM with pixeled readout	4	4	10	4	4	8
		Gas	1		2	0	0	1
		Fe electronics	3	1	4	0	0	0
		Small Items	2		3	0	0	1
		total	10	5	19	4	4	10
	Equipment	DAQ system				10	0	
		total	0	0	0	10	0	0
	Travelling	MPGD-NEXT annual meeting	0	1	0	1	1	1
		test beam activity	3	1 (s.j.)	3	2	1 (s.j.)	2
		total	3	1	3	3	1	3
	Grand Total		13	6	22	17	5	13

ANAGRAFICA ROMA TRE E NAPOLI

Preventivi 2017 > CSN V > MPGD_NEXT > Roma III > Modulo EC/EN 7

Modulo EC/EN 7

A cura di: Mauro Iodice

Ricercatori						
	Nome	Età	Contratto	Qualifica	Aff.	%
1	**Biglietti Michela**		Dipendente	Ricercatore	CSN I	**10**
2	**Iodice Mauro**		Dipendente	Ricercatore	CSN I	**20**
3	**Petrucci Fabrizio**		Associato	Prof. Associato	CSN I	**20**
				Numero Totale Ricercatori	3	FTE: 0.5

Preventivi 2017 > CSN V > MPGD_NEXT > Napoli > Modulo EC/EN 7

Modulo EC/EN 7

A cura di: MASSIMO DELLA PIETRA

Ricercatori						
	Nome	Età	Contratto	Qualifica	Aff.	%
1	**Alviggi Maria Grazia**		Associato	Prof. Associato	CSN I	**20**
2	**Canale Vincenzo**		Associato	Prof. Associato	CSN I	**20**
3	**Della Pietra Massimo**		Associato	Prof. Associato	CSN I	**20**
4	**Di Donato Camilla**		Associato	Prof. Associato	CSN I	**20**
5	**Sekhniaidze Givi**		Dipendente	Ricercatore	CSN I	**20**
				Numero Totale Ricercatori	5	FTE: 1.0