Irfu - CEA Saclay
Institut de recherche sur les lois fondamentales de l'Univers

Overview of Micromegas R&D Work and Plans

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EIC meeting – Temple University – May 2015

Summary

1. The Micromegas History and Principles

2. Micromegas Technology development

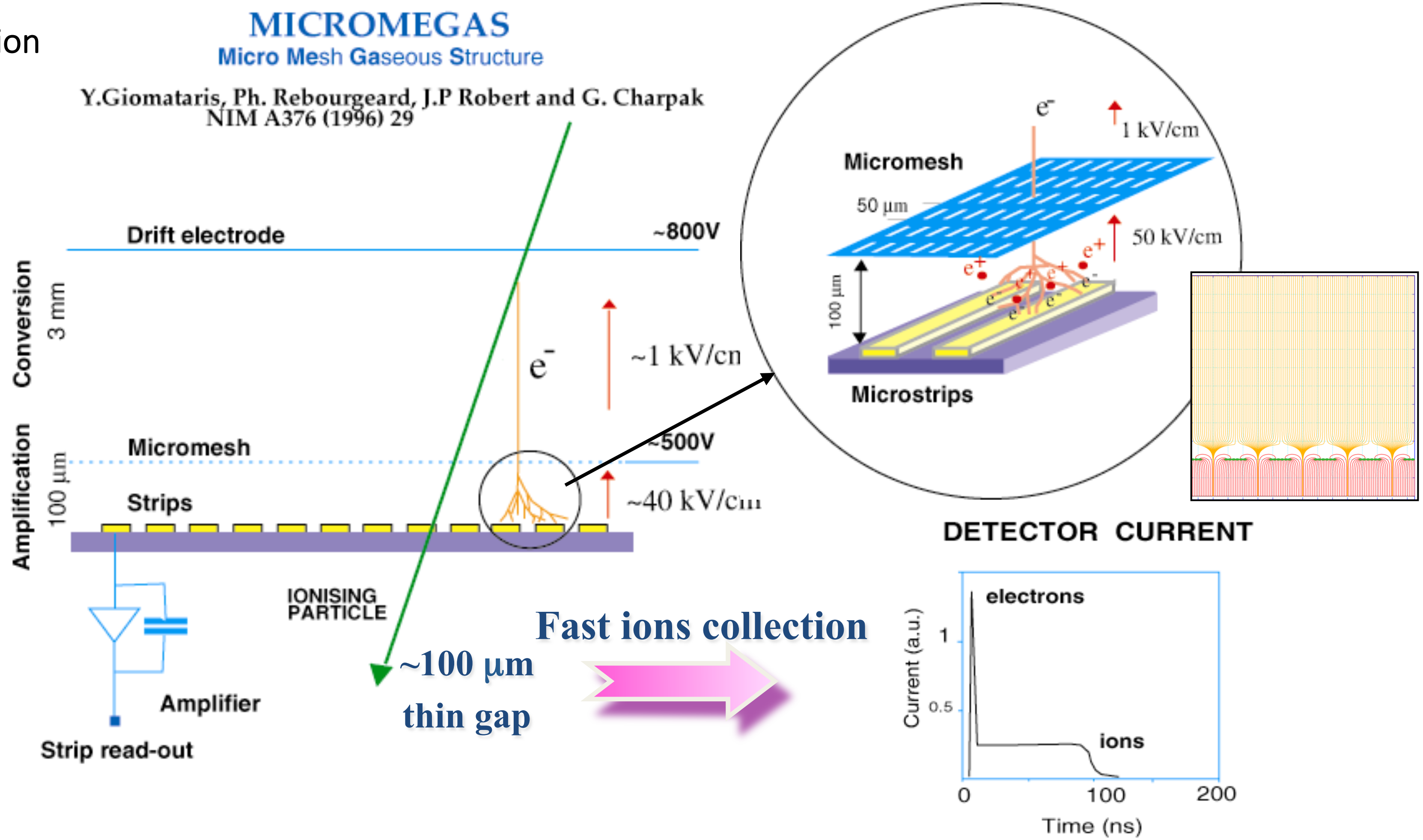
3. The Electronics Development for Micromegas

4. Characterization of Micromegas Detectors at Saclay

The Micromegas History

1996

invention

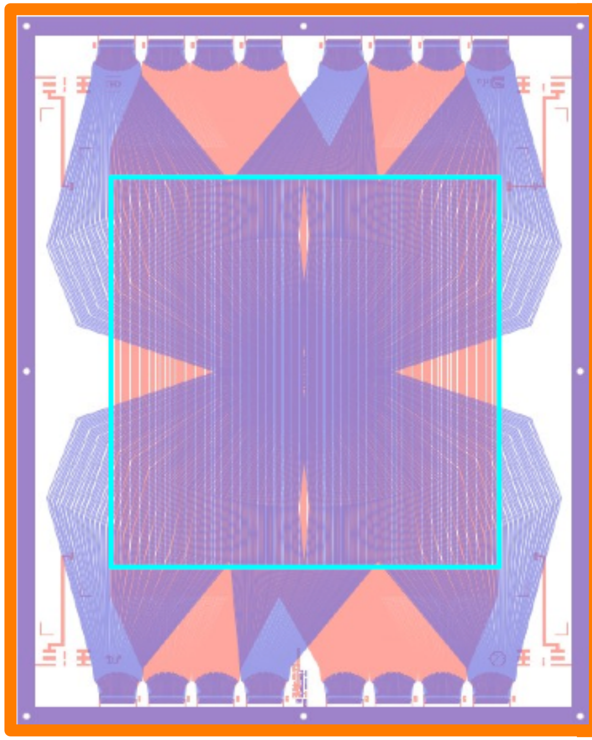


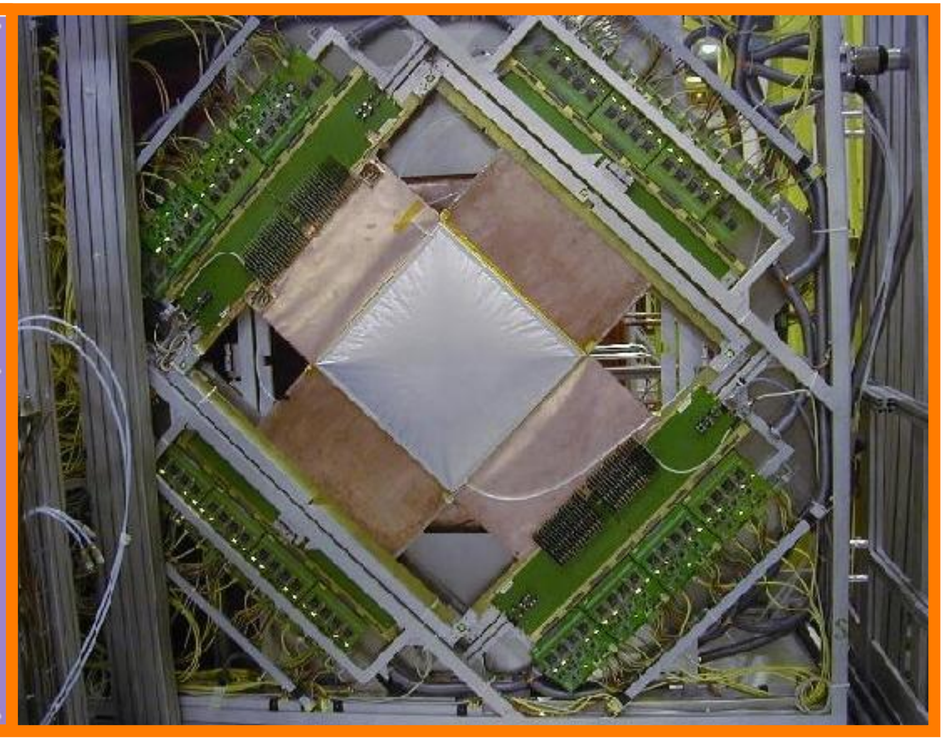
The Micromegas History

1996 → invention

2002 → 1st use in expt

- *COMPASS @ CERN*
- *A decade of smooth operation*
- *No ageing seen*





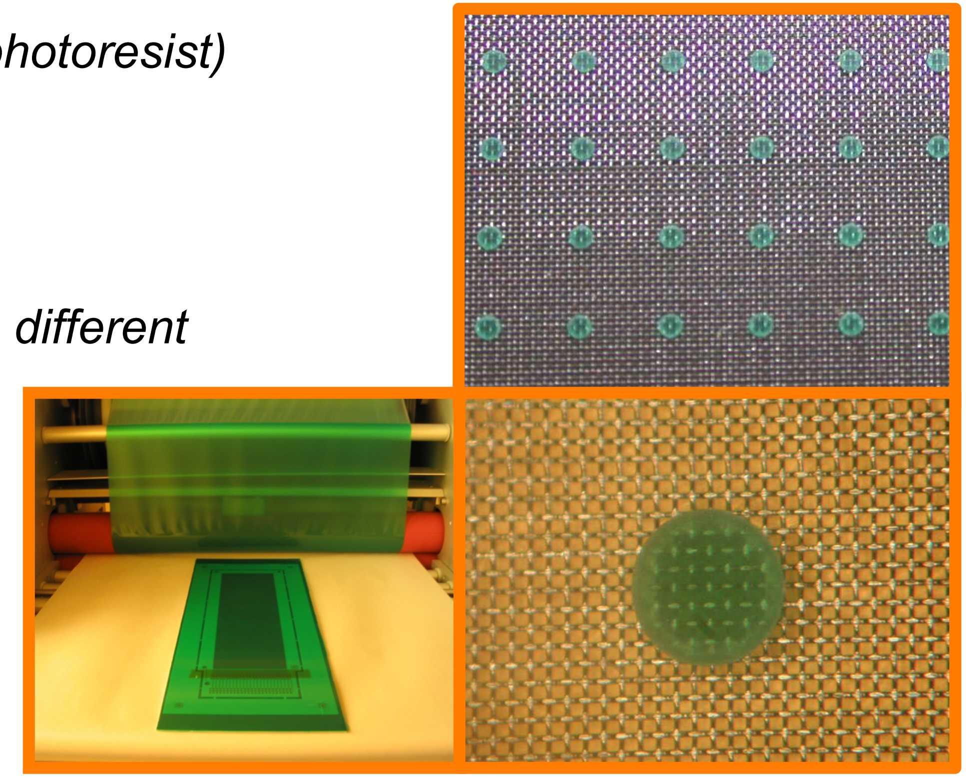
The Micromegas History

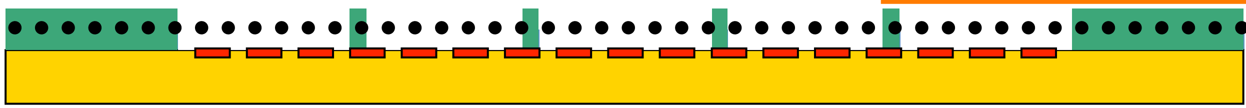
1996 → invention

2002 → 1st use in expt

2006 → bulk process

- *More robust (mesh is embedded in photoresist)*
- *Simplified mechanical structure*
- *Ability to use thin PCBs and produce different shapes (cylindrical detectors !)*
- *Ability to industrialize the process*
- ***Cheap !!!***





The Micromegas History

1996 — invention

2002 — 1^{st} use in expt

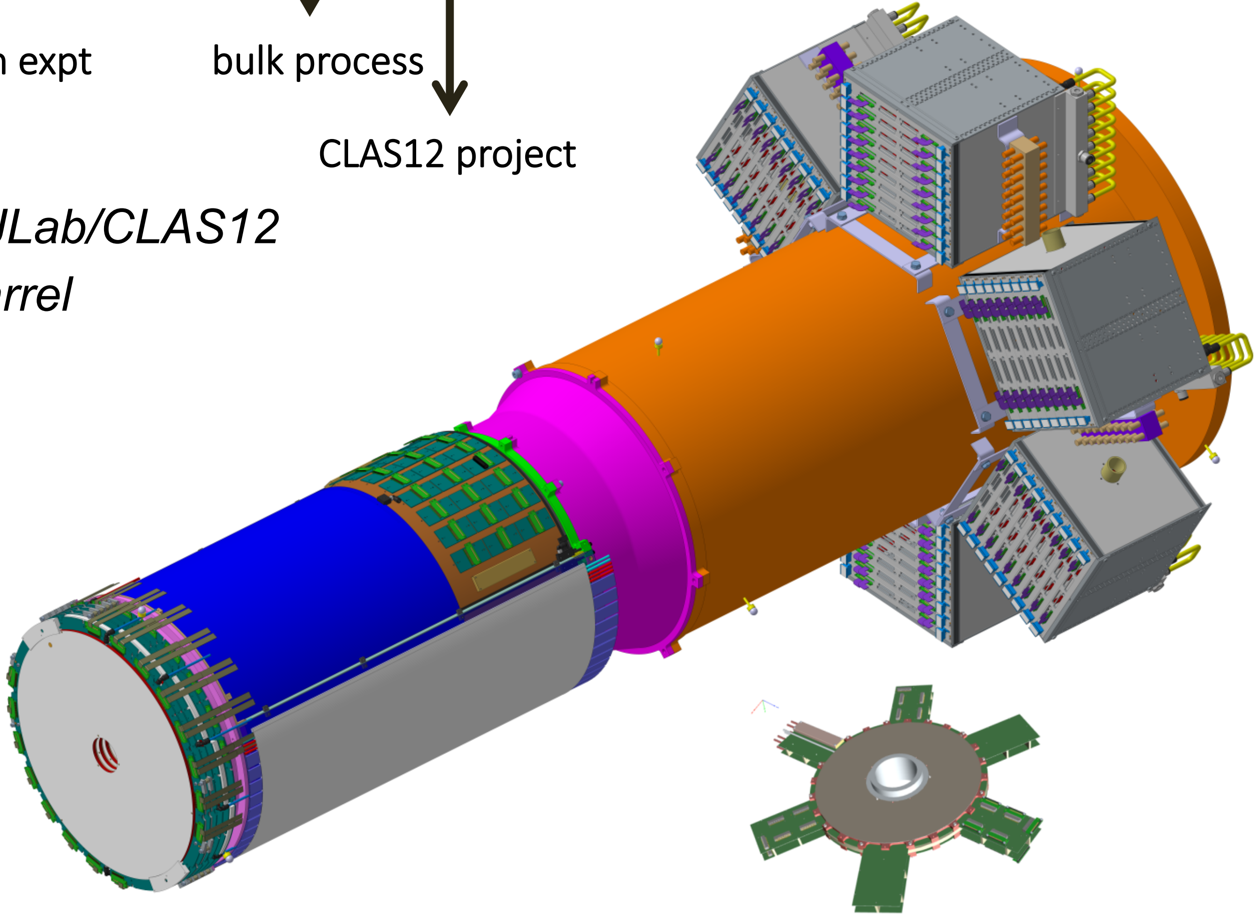
2006 — bulk process

2007 — CLAS12 project

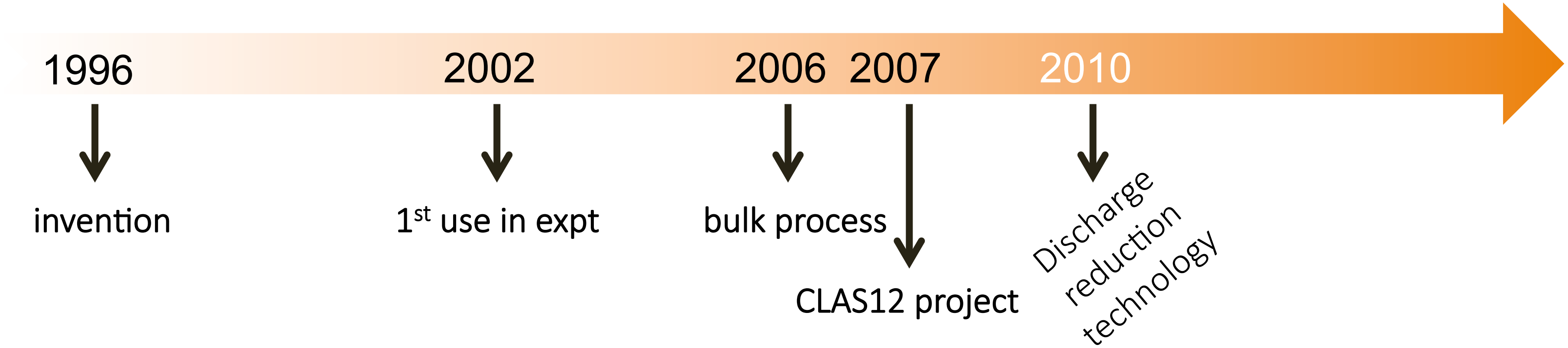
- *Micromegas tracker for JLab/CLAS12*
- *Forward + Cylindrical Barrel*
- *Triggered a lot of R&D*

- **Barrel: 18 tiles**
- **Forward: 6 disks**
- **FPT: 4 rings**
- **> 4 m^2 & 24k channels**

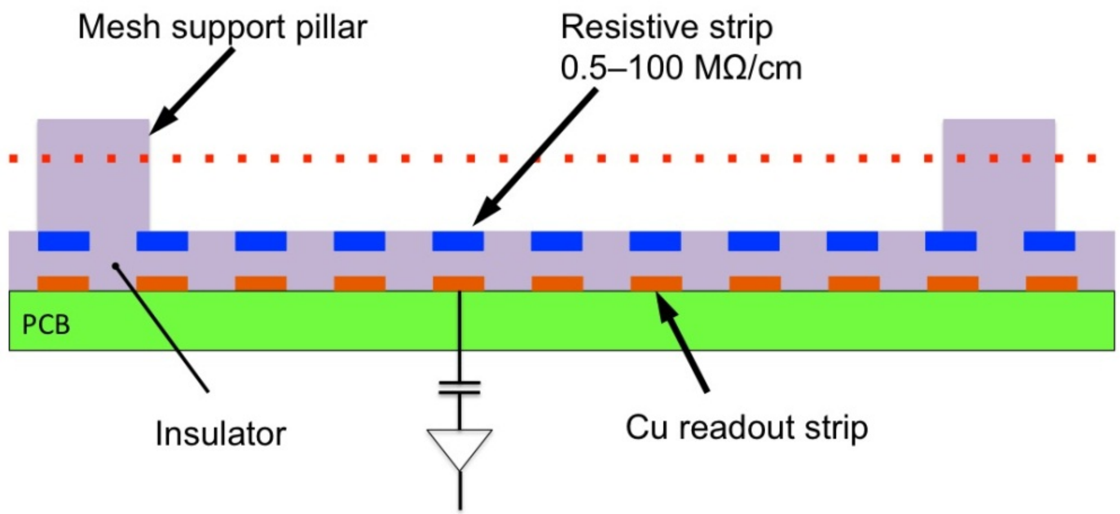
- **5 T magnetic field**
- **High rate (up to 30 MHz)**
- **Remote elec. (1.5-2 m)**
- **Thin: ~ 0.3% X_0 / layer**
- **Resistive technology**



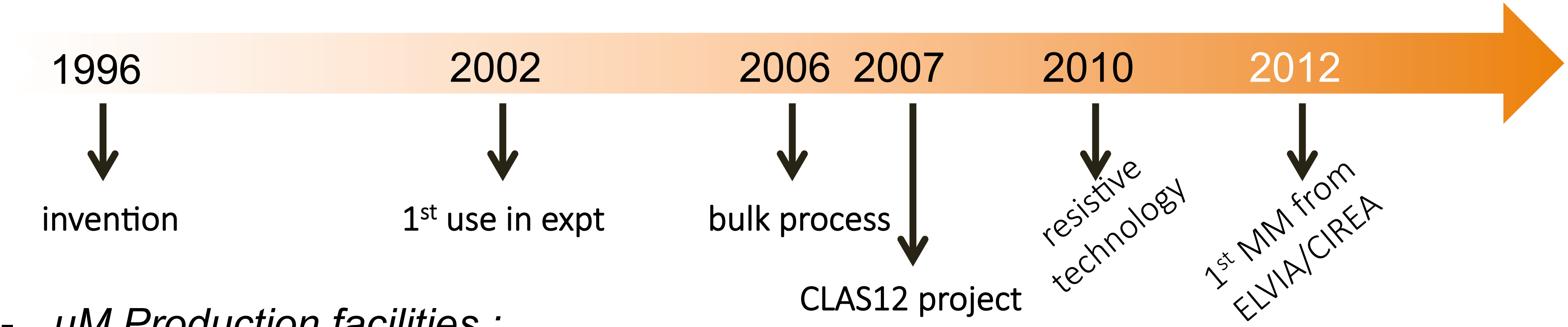
The Micromegas History



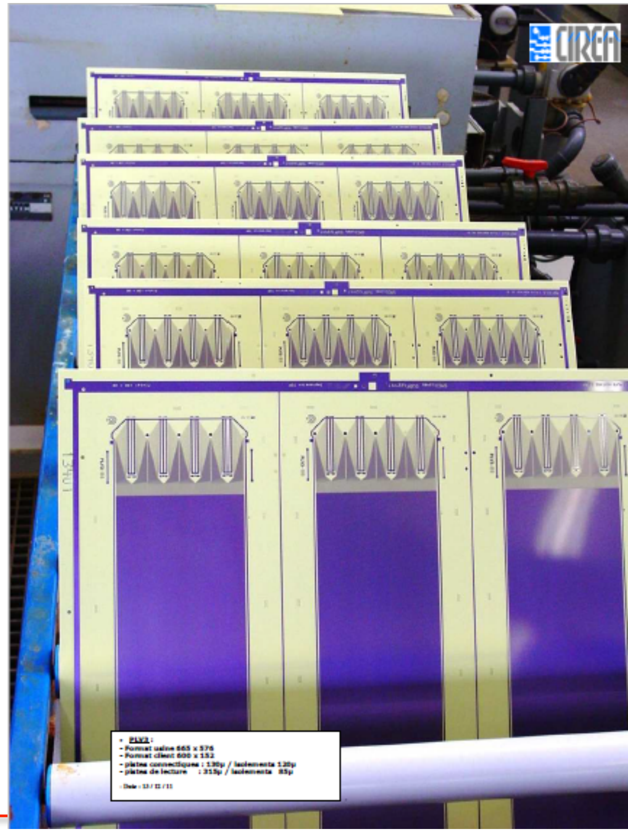
- *Capacitive readout*
- *Quenches sparks (max 1V HV drop)*
- *No ageing seen*
- *Higher flux capability*



The Micromegas Principle



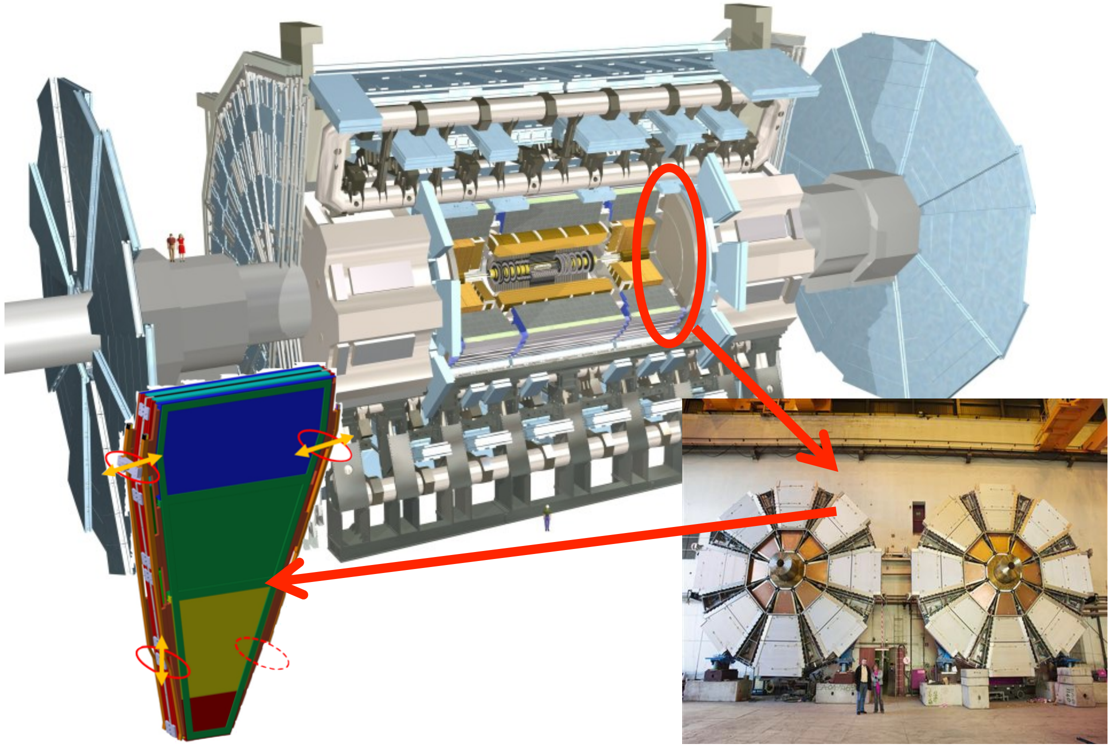
- *μM Production facilities :*
  - *CEA / CERN / ELVIA / ELTOS*
- *1st industry prototype successfully tested for CLAS12*
- *ELVIA*
  - *Large size*
  - *Bulk*
  - *Resistive*
  - *Assembly*



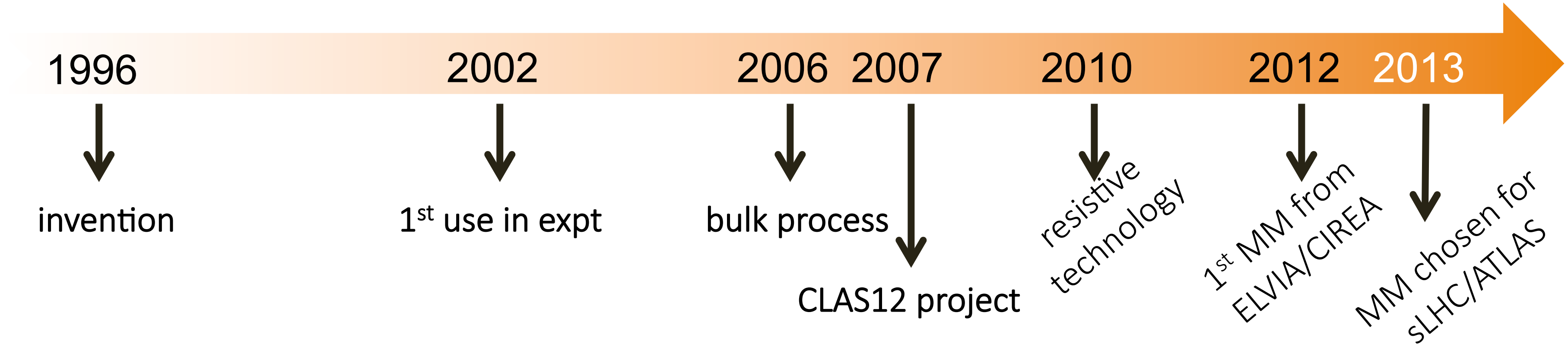
The Micromegas Principle – New Experiments

- 1996 – invention
- 2002 – 1st use in expt
- 2006 – bulk process
- 2007 – CLAS12 project
- 2010 – resistive technology
- 2012 – 1st MM from ELVIA/CIREA
- 2013 – MM chosen for sLHC/ATLAS

- *ATLAS small wheel (NSW)*
- ***1200 m²** of Micromegas detectors to build !*
- *Industrialization process intensified*



The Micromegas Principle – New Experiments



Micromegas TPC
- *-> MINOS*
- *-> T2K*
- *-> HARPO*
- *-> ILC*

Curved Micromegas
- *-> ASACUSA*
- *-> CLAS12*
- *-> EIC*

Flat Tracking Chambers
- *-> CLAS12*
- *-> ATLAS*

Multiplexed Micromegas
- *-> Watto / M^3*
- *-> GBAR*

Hybrid
- *-> COMPASSII*

Micro-Bulk
- *-> CAST*
- *->N-TOF*

R&D on Micromegas

- Resistive Technologies
- Cylindrical Detectors
- Hybrid
- Micro-Bulk
- Multiplexed Micromegas

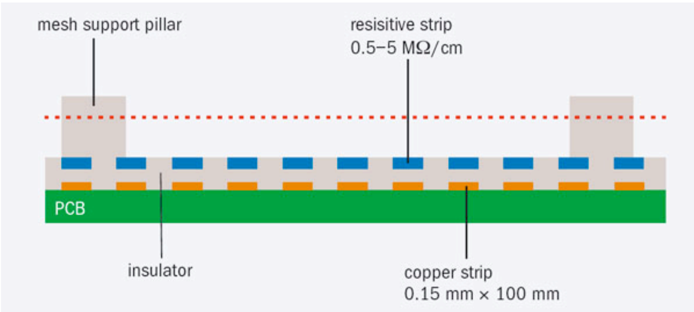
Resistive Micromegas

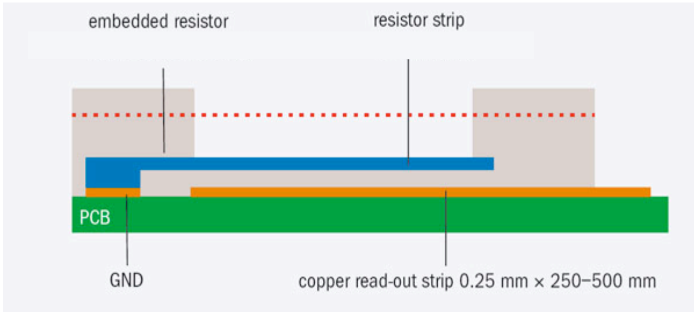
Resistive technology, why?

-> To avoid discharges and obtain a higher gain in a safe and stable fashion
-> Ageing
-> High rate
-> No Protection circuit *(->better SNR)*
-> Larger Cluster Size *(Possibility to use 2D readout)*

How ?

-> Resistive strips are laid on top of the copper strips above an insulator (kapton foil)
-> This kapton foil with the resistive strips is produced using resistive ink and serigraphy
-> Connection to ground is made with vias and silver paste
-> The micro-mesh is put on top of the resistive layer using the bulk technology

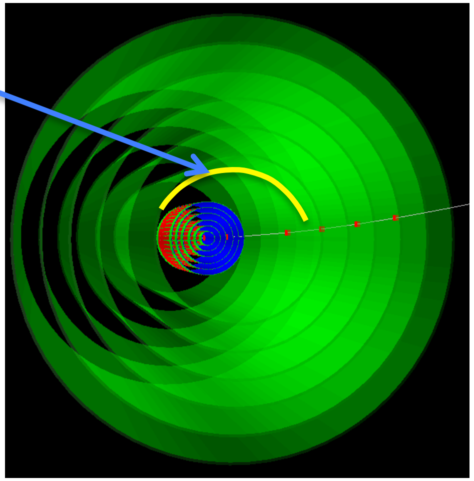




Sections of a resistive Micromegas, perpendicular to the strips (left) and along the strips (right)

=> See results on CLAS12 Forward and Barrel

Cylindrical Micromegas



Goal :

-> Very Light Cylindrical 1D/2D Detectors

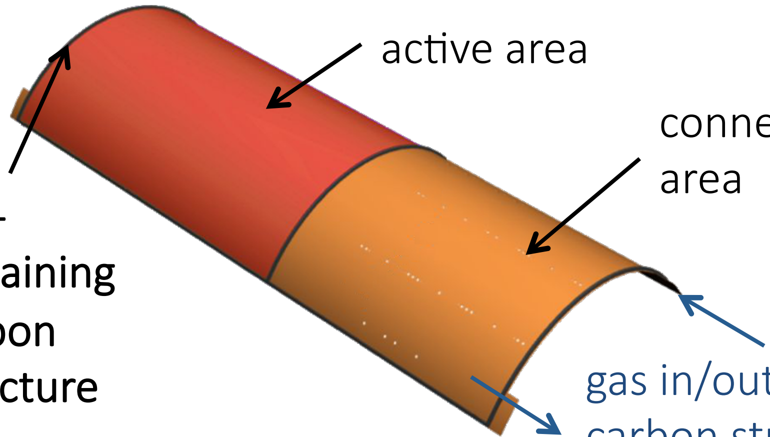
-> Curvature down to 10 cm radius ok

-> Resolution of 100 µm and 10ns

-> Large size (~50 cm length)

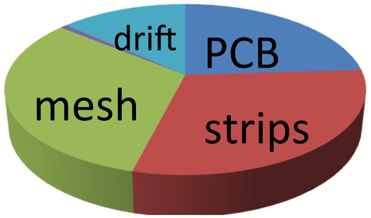
-> Operation in high magnetic field up to 5T (low drift space / high drift field)

-> Unique geometry, good for full angle coverage



Material Budget

- active area : 40x45cm^2 r=225mm
- 575 µm pitch
- resistive strips
- kapton drift
- 200µm PCB, total 0.35% X_0/layer



=> See results on CLAS12 Barrel and AMT

GEM + MM = Hybrid

Hybrid technology, why?

-> To avoid discharges by sharing the Gain between the Micromegas and the GEM

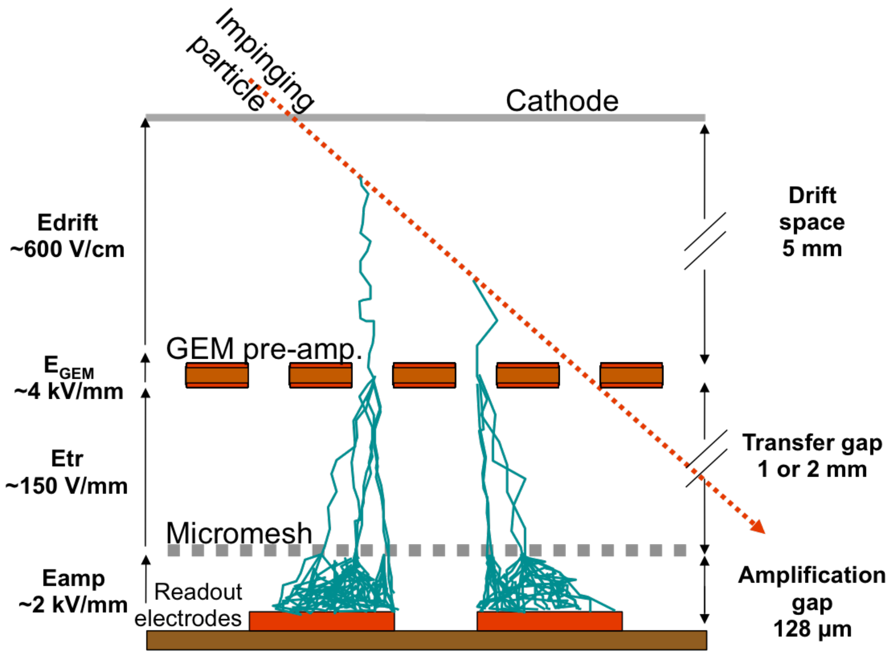
-> Diffusion of the primary el. cloud

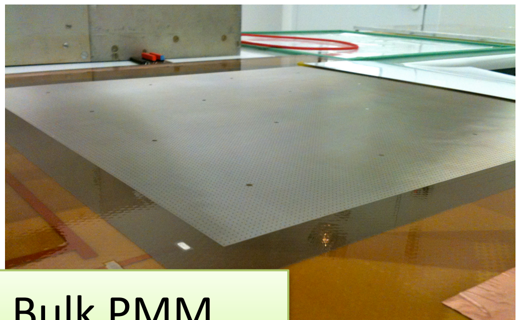
-> Larger Cluster Size

-> Pixel Compatible

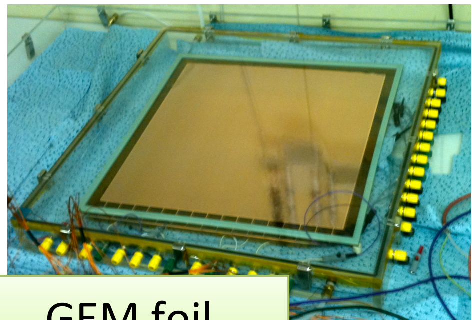
How ?

-> GEM foil is held by frame and pillar-like spacers at 1-2 mm from the Micromegas readout

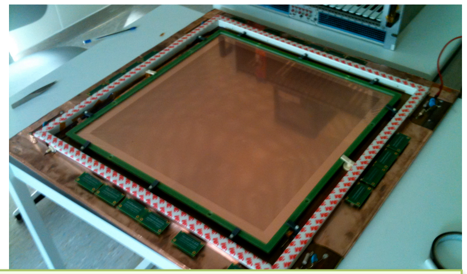




Bulk PMM



GEM foil



PMM assembled

Hybrid @ COMPASS - Results

CERN SPS BEAM :

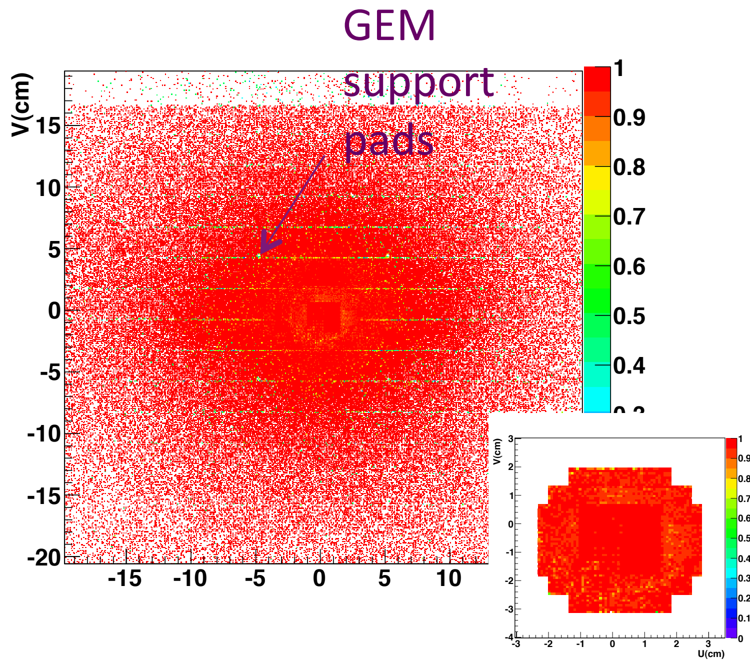
100 to 200 GeV muons up 4x10^7 μ/s
190 GeV hadrons up 10^7 h/s

Detectors:

12 detectors in production
40x40cm active area detectors
1024 strips + 1024 pixels
20MHz integrated flux
5mm drift area, Ne+10%C2H6+10%CF4

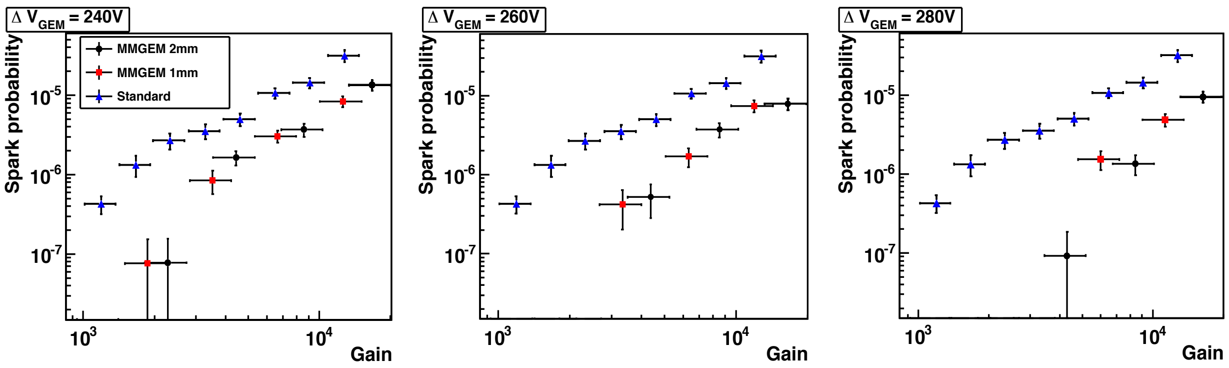
Material budget :

0.319% X0 (Std MM: 0.287% X0, pixel GEM 0.4% to 0.7% X0)
+ GEM 0.067% X0 (0.035% X0 for GEM with 2µm of Cu)



Performances :

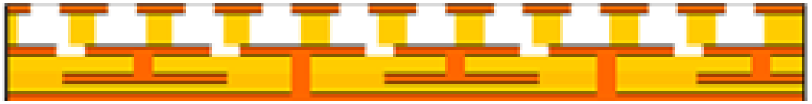
70µm spatial resolution
9ns time resolution
98% efficiency
10 to 100 discharge rate reduction



Micro-Bulk Micromegas

Micro-Bulk Micromegas :

- 50µm Kapton foil based detectors
- GEM-like technology with strips
- Small area



Now 2D readout :

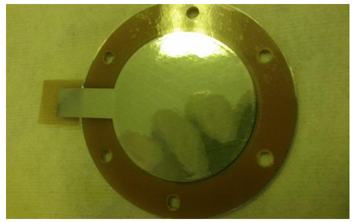
- X/Y read/out with a single 50um foil
- Similar holes and pitch as previous Micro Bulk
- Low mass, Lower cost , better yield expected
- No charge sharing between X and Y pads

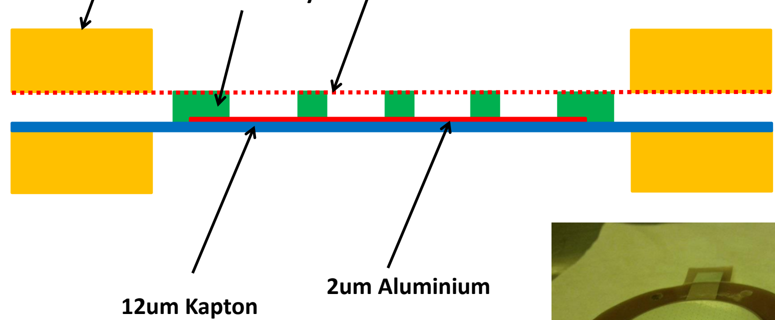
Very low material

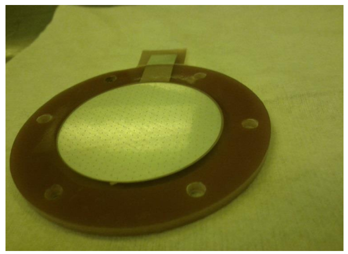
Radio pure

Fast Time resolution

- 200µm drift space
- Photocathode
- 30 ps time resolution !





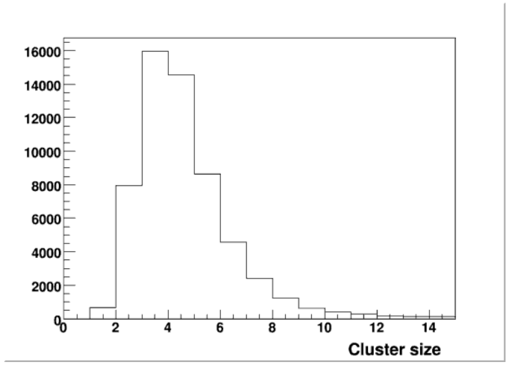


Total : 25um Kapton + 4um Aluminium

« Genetic » multiplexing

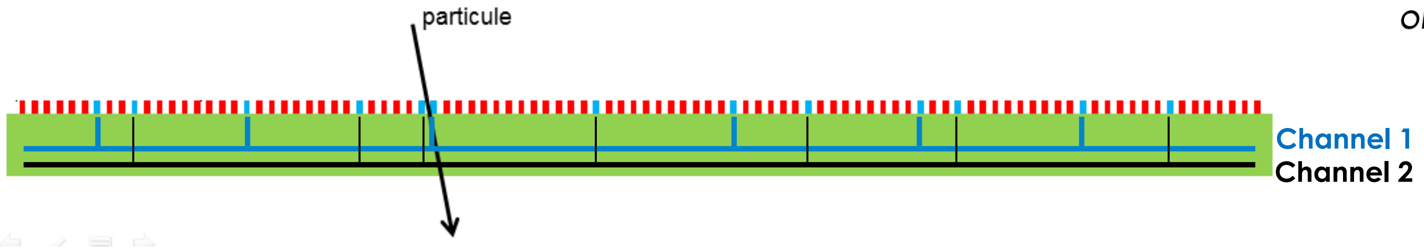
Read large area with a few channels using redanducy :

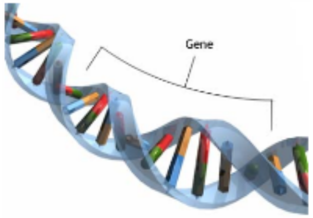
→ *in most cases, a signal is recorded on at least 2* ***adjacent*** *strips*



We can make use of this redundancy, and combine channels with strips in such a way that any given pair of electronic channels contains one and only one pair of adjacent strips.

The sequence of channels uniquely codes the position on the detector…





→ *the connection {channels}$_n$ ↔ {strips}$_p$ can be represented by a p-list of channel numbers*

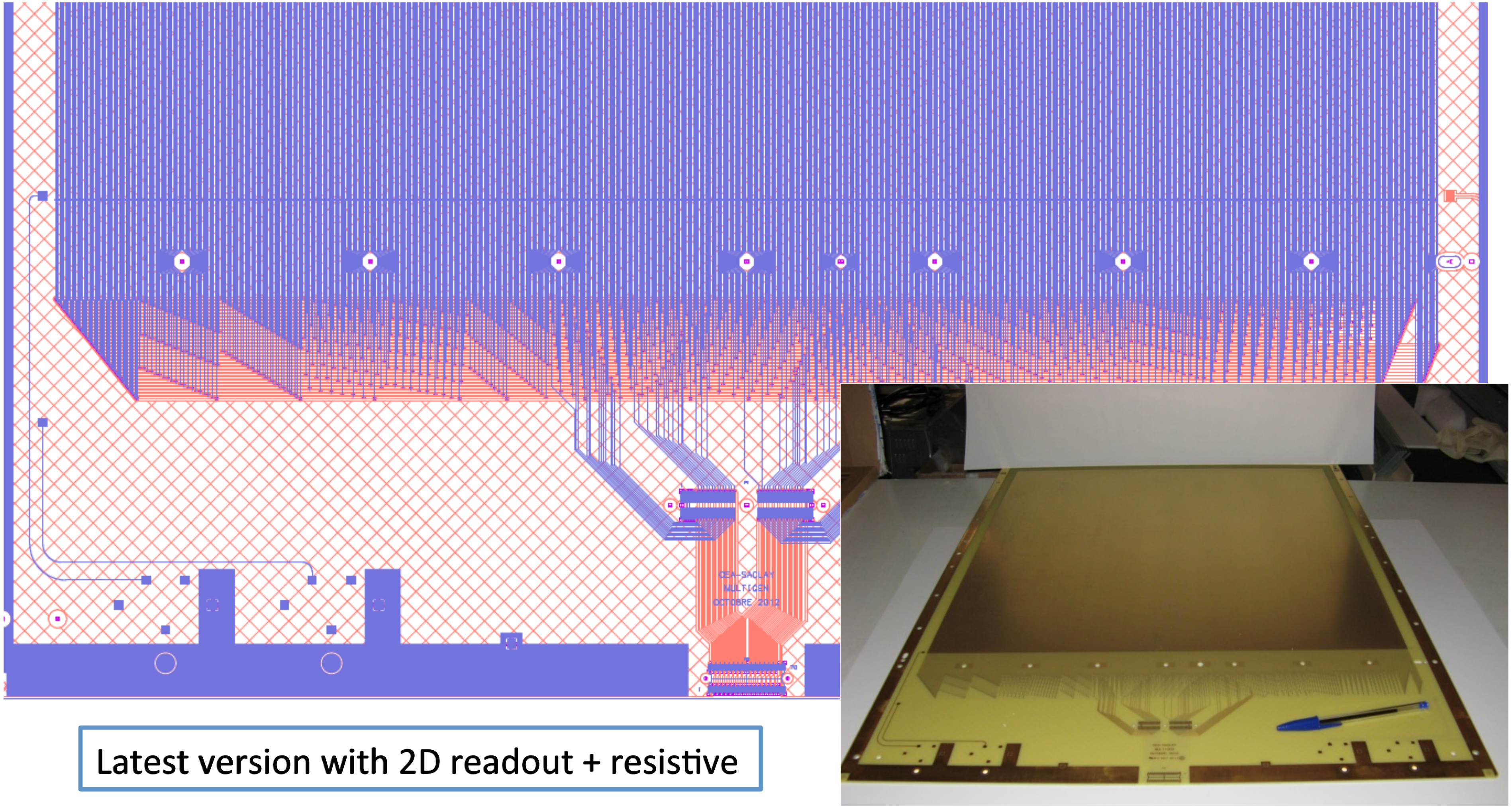
For n channels, there are *a priori* n(n-1)/2 unordered doublets combinations; thus one can equip a detector with at most p = n(n-1)/2+1 strips.

S. Procureur *et al.*, NIM A729 (2013) 888
Licensed under patent # 12 62815

Genetic multiplexing: MultiGen Detectors

50x50 cm² active area, read with n = 61 channels

- 488 micron pitch - p= 1024 strips - could have equiped up to 61x60/2+1=1831 strips (~90 cm)

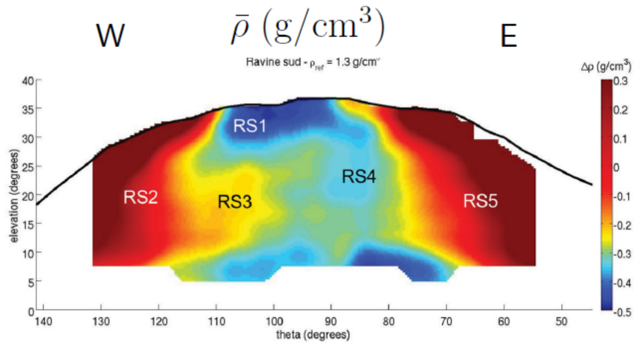


Latest version with 2D readout + resistive

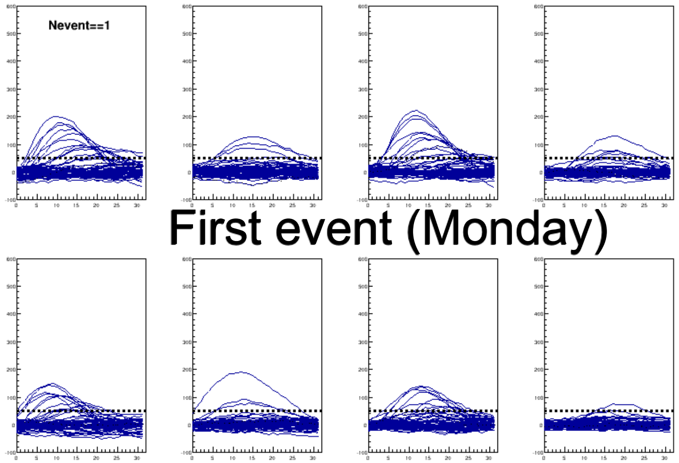
Genetic multiplexing: low-flux applications

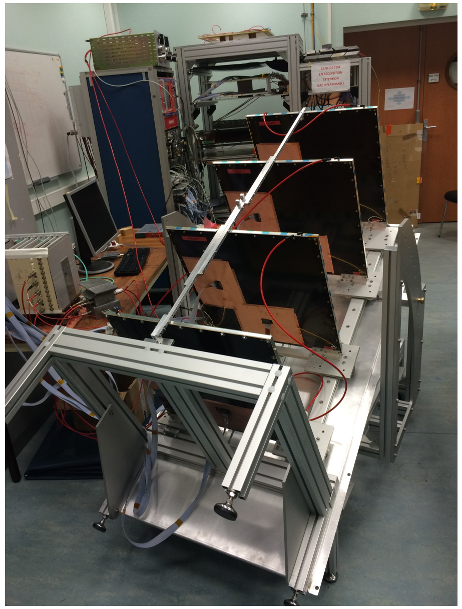
- **Homeland security / Detector characterization / Archeology**
- Muon tomography for **volcanology**: requires large detectors with low consumption

first results with 80x80 cm² planes of scintillators (~1 cm resolution)



- **Full scale tomography happening now with the water tower of Saclay ! (Watto)**





Electronics development for Micromegas

- Two DAQ systems and Two different ASICS developed specificly for MPGDs

DREAM Based electronics for CLAS12

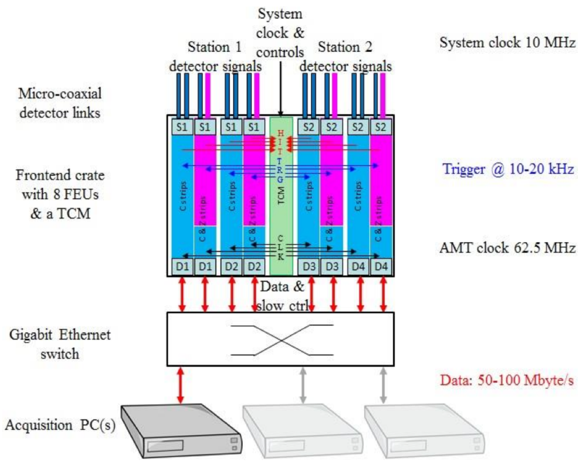
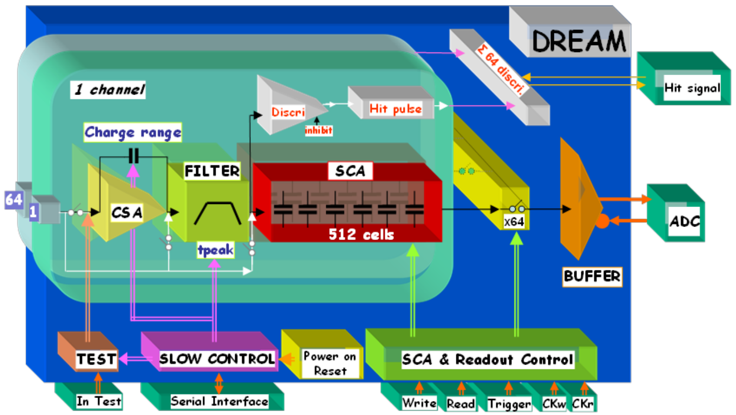


Fig 2. AMT readout architecture



AGET Based electronics for the MINOS TPC

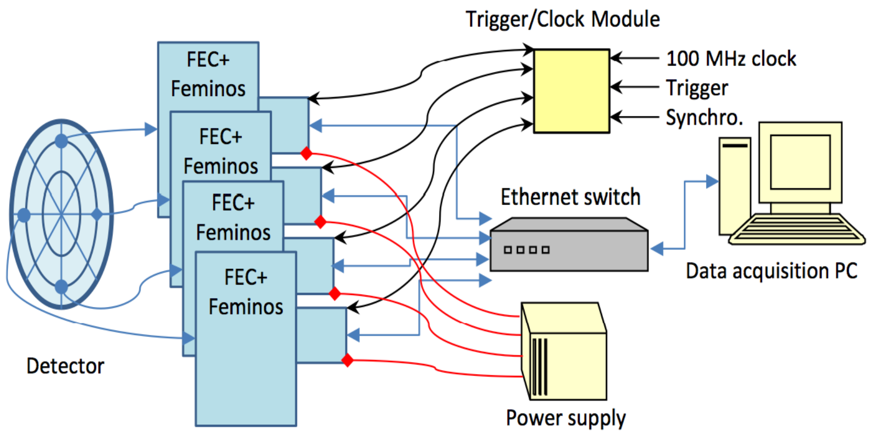
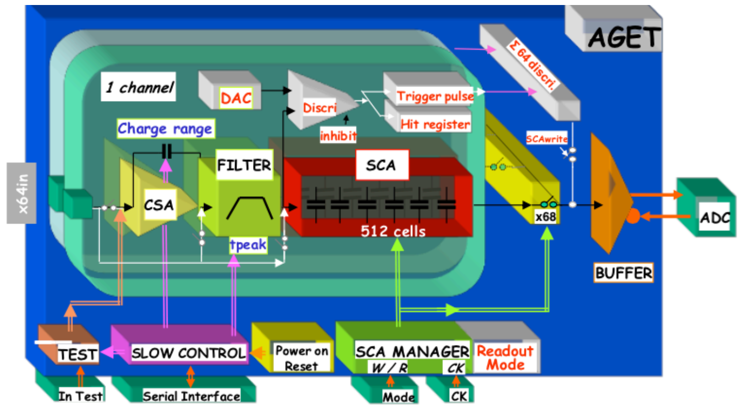
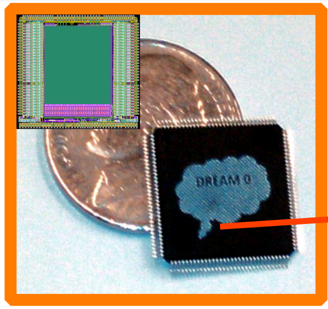
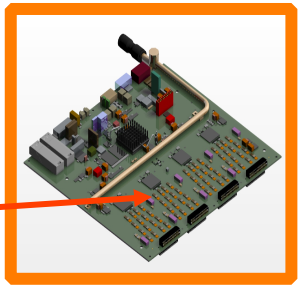


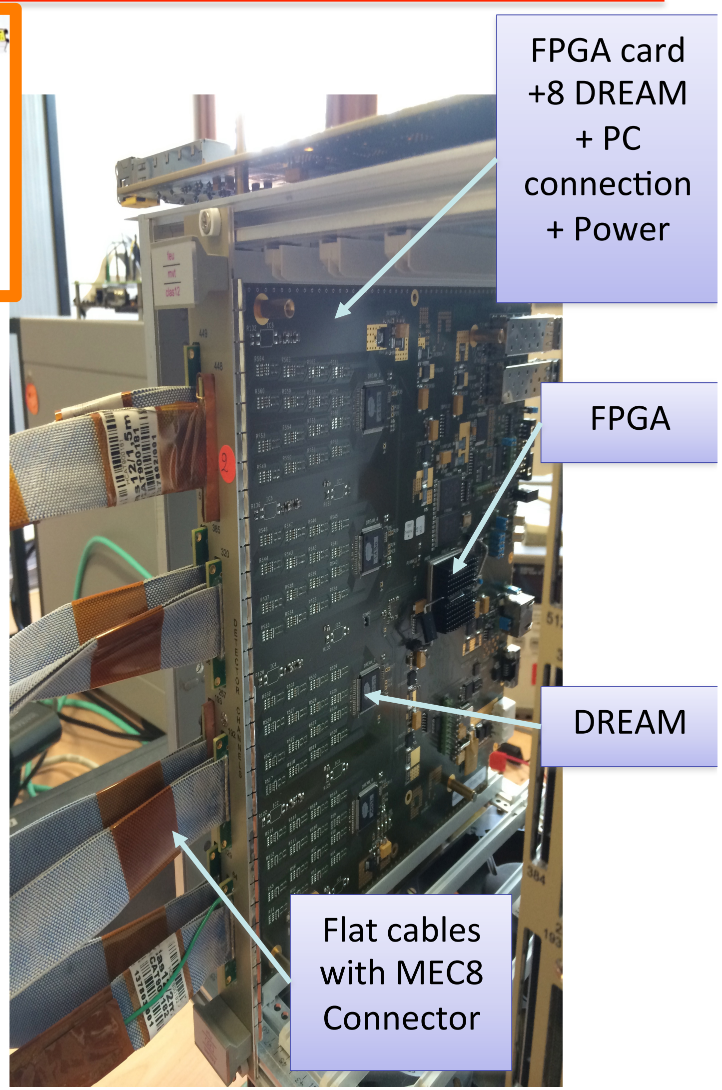
Fig. 1. Feminos application example.



DREAM (Dead-timeless Read-out Electronics ASIC for Micromegas)







One FEU DREAM

DREAM ASIC

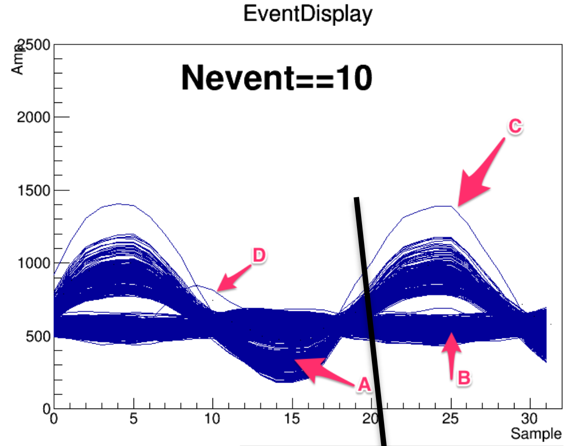
- Evolution of AFTER and APV25 chips
- 64 Channels / 512-cell deep analog memory per channel
- Tailored for high capacitance detectors (MPGDs)
- Dead-time free (Circular buffer)
- Low noise : 2100e- at 200 pF (**cable**+detector)
- 4 gain ranges: 60 fC, 120 fC, 240 fC, 1 pC
- 16 programmable peaking times: from 50 ns à 1 μs
- Sampling rate: 1- 100 MHz

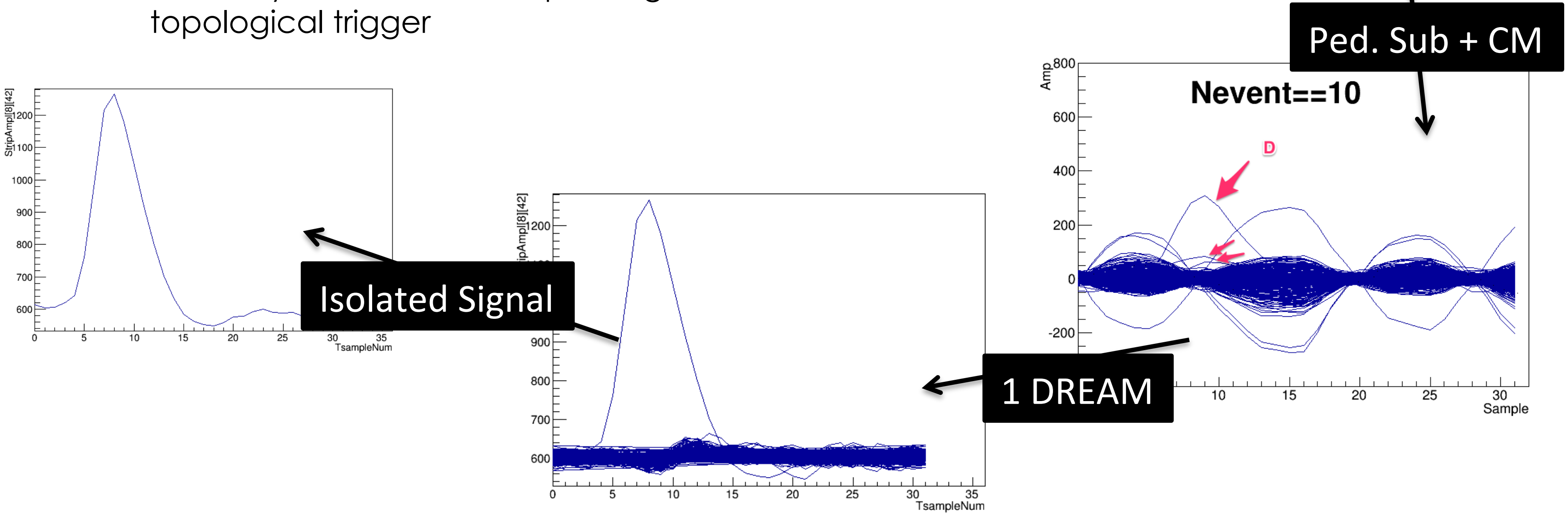
Front-End Unit cards

- 8 DREAM per Front-End Unit card (FEU) 8x64 = 512 channels
- 1 FEU can run in stand alone mode
- Up to 24 FEUs with a Trigger Clock Module (TCM)
- Connection to PC via 1Gbit Ethernet (RJ45) or/and optical fiber (2.5 Gbit)
- Has been tested with 20kHz of fully random trigger
- TCM card able to deal with internal and external trigger

Online data correction / Self-triggering

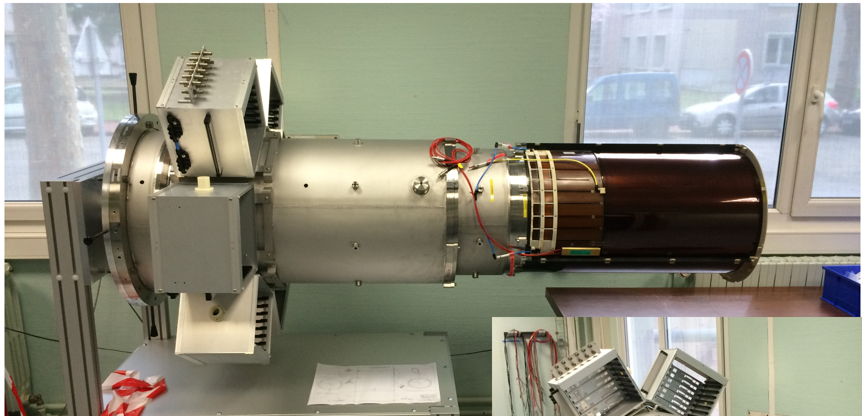
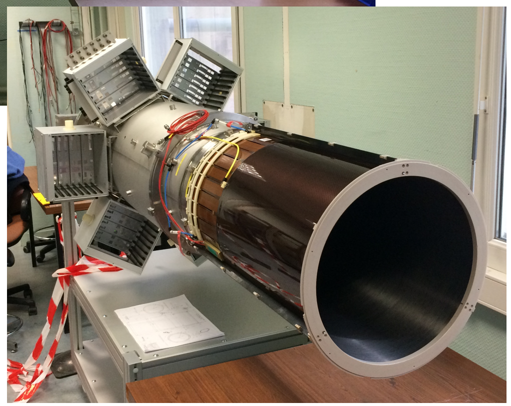
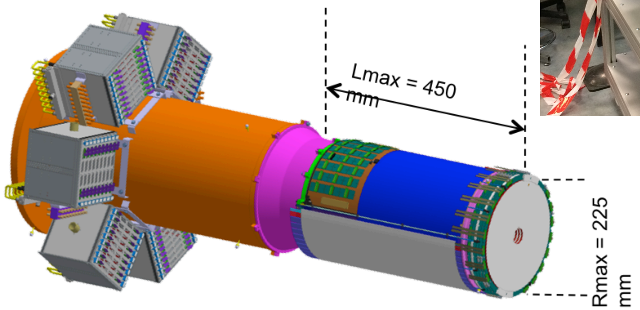
- Large capacitance creates important coherent noise
- Online (or offline) corrections :
  - Pedestal subtraction
  - Common noise subtraction
  - RMS Calculation
  - Zero suppression
- **Self-triggering firmware working and used in real experimental conditions**
- Possibility to selected complex logic for an advanced topological trigger

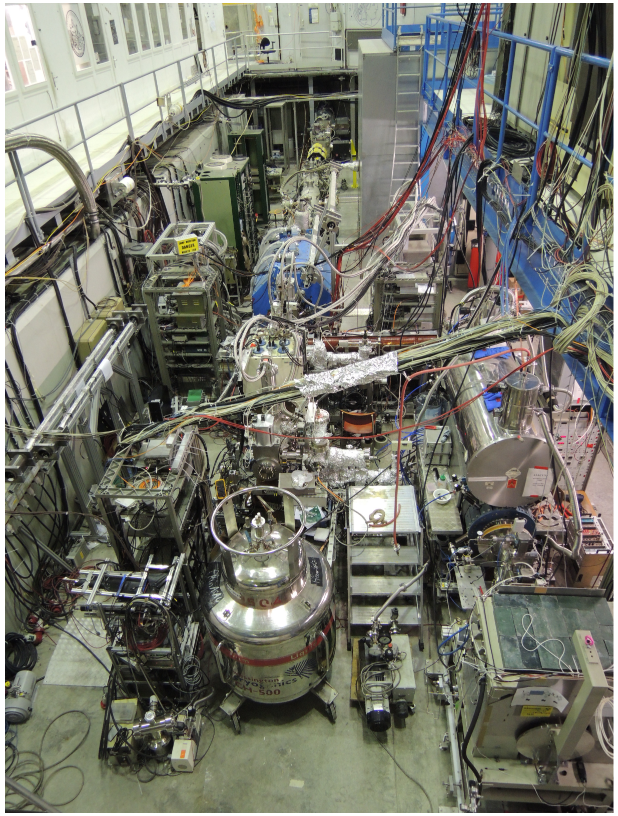




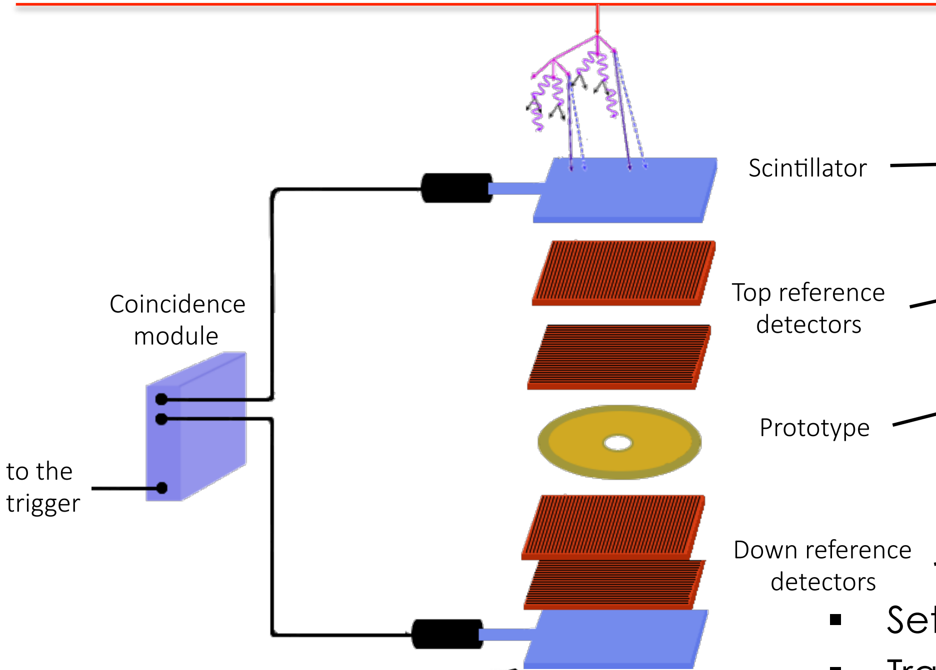
Latest Micromegas Detectors for CLAS12 and ASACUSA

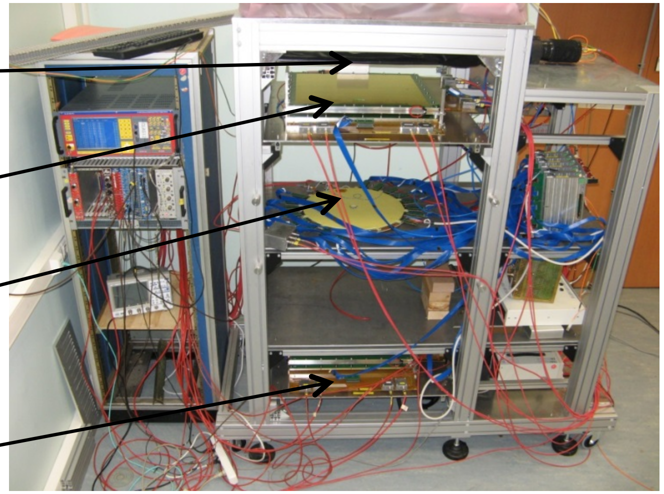
- Resistive disk detectors for CLAS12
- Barrel
  - CLAS12
  - ASACUSA

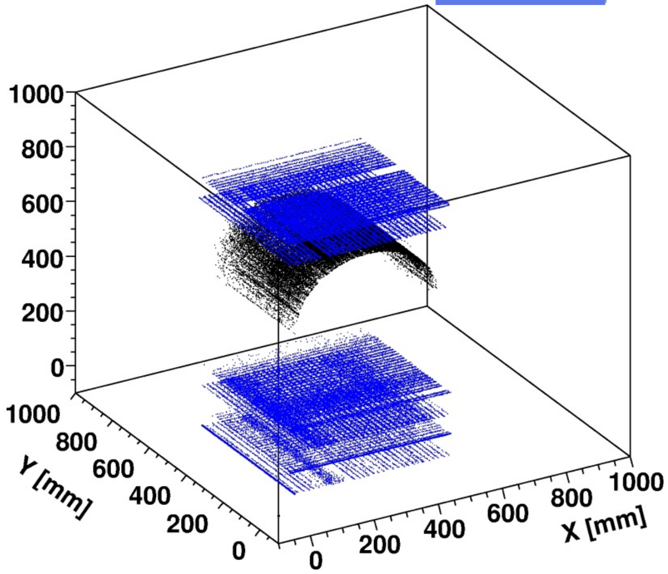






Detector characterization at Saclay : Cosmic Test Bench



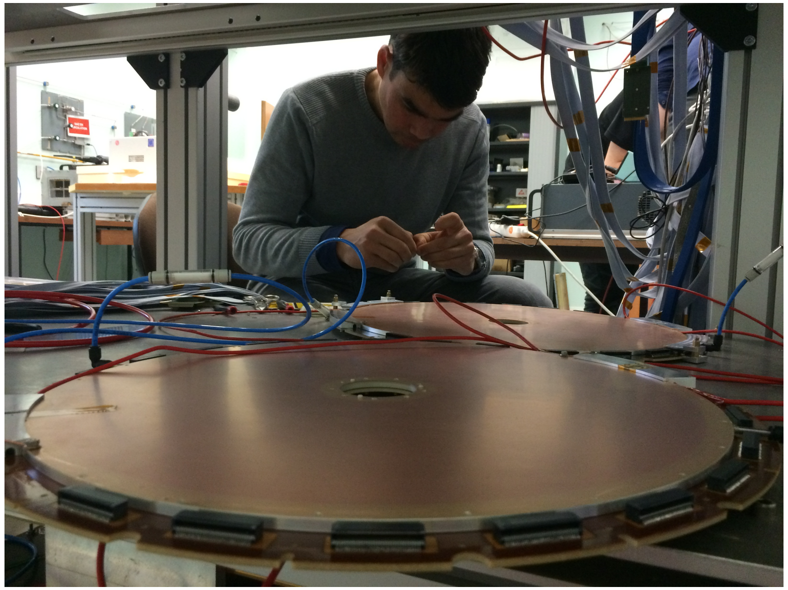


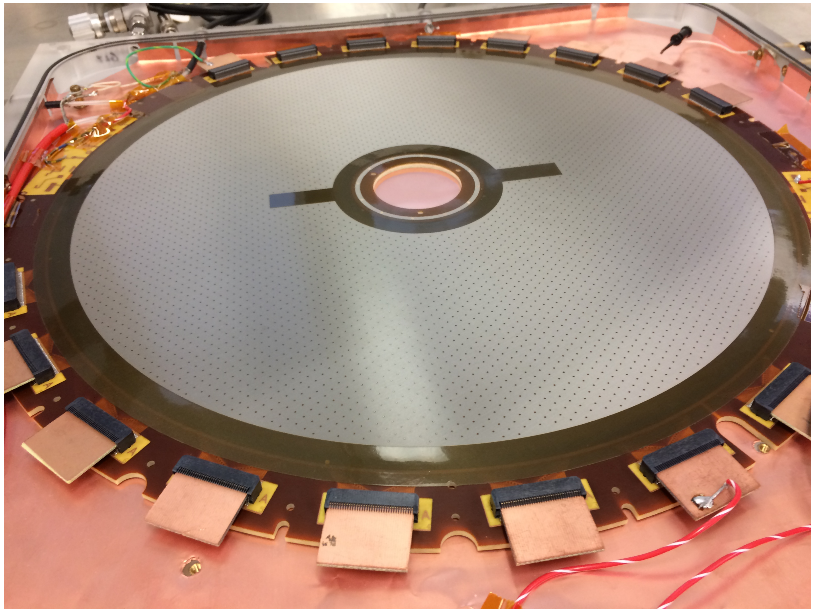


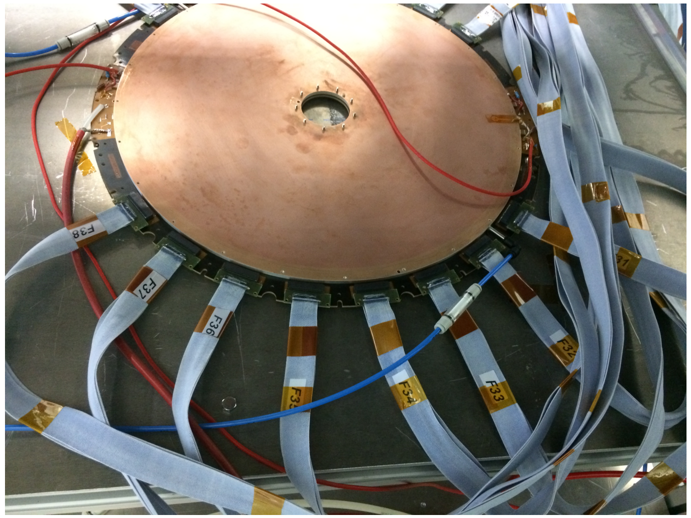
- Setup to characterize in 2D the prototypes
- Tracking detectors : MultiGen 2D x4 (8 Connectors)
- Fully equipped with DREAM FEE
  - 1 FEU for tracking det.
  - 5 Protected FEUs
  - 4 Unprotected FEUs
- 24 Positive + 24 Negative HV
- Gas mixing system + pre-mixed bottles
- Trigger control module, trigger time resolution below 3 ns, Projected track resolution of ~100 μm
- 60 Hz trigger rate, 43% track reconstruction efficiency
- 1h to get an efficiency point

Forward disk for CLAS12

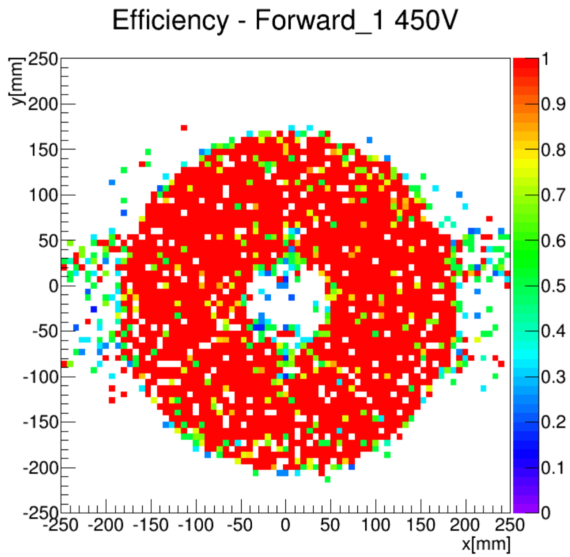
- 6 Disks located after the target
- Resistive strips divided in 2 zone inner/outer
- 1024 strips, pitch 525 µm
- Deported electronics
- Dimensions: 430 mm diameter disk with a 50 mm diameter hole at the center
- High counting rate (10 MHz)
- High magnetic field (5 T)

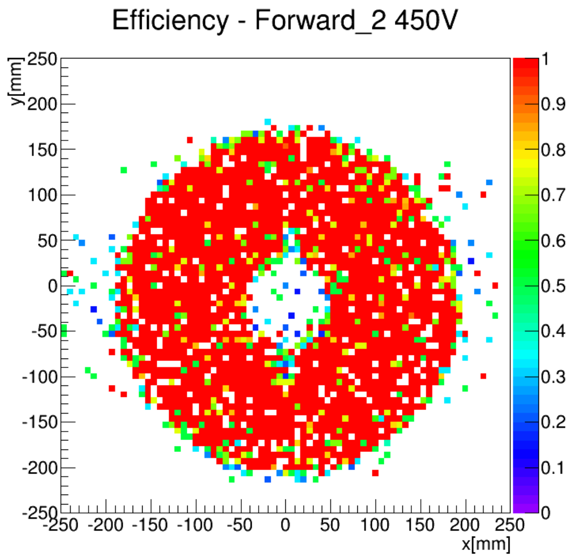


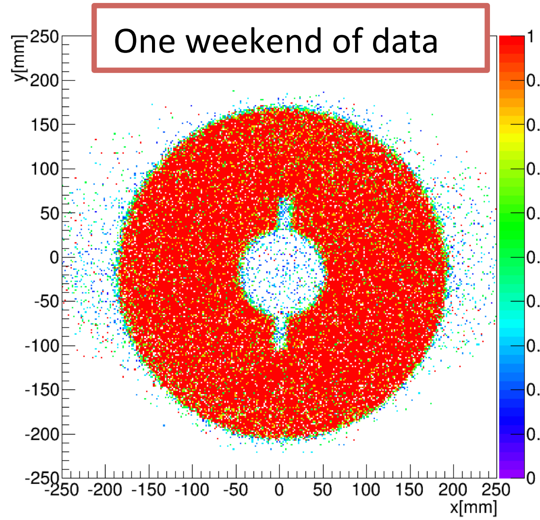


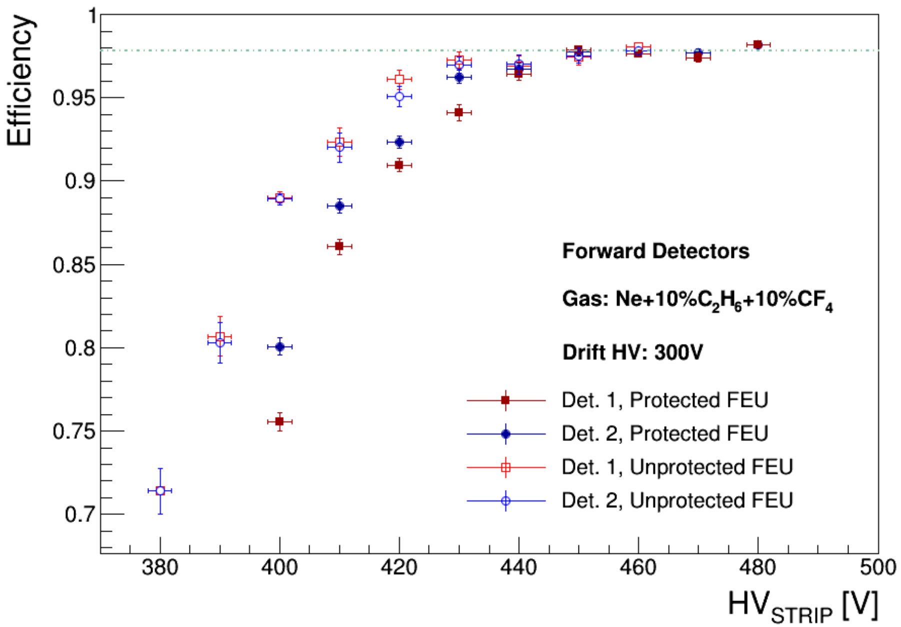


Forward disk for CLAS12: Production

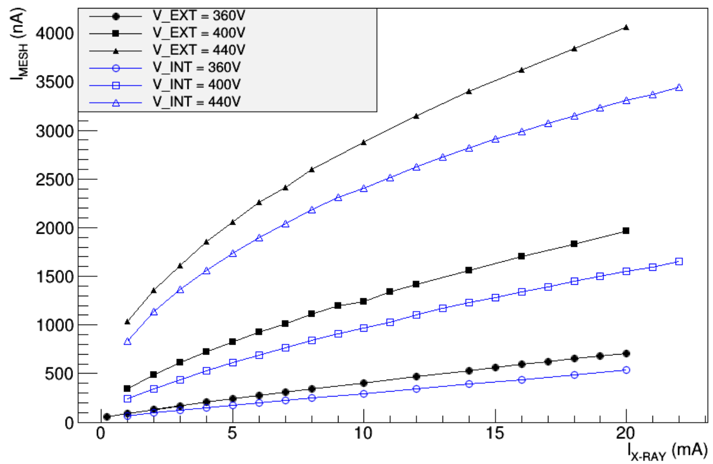






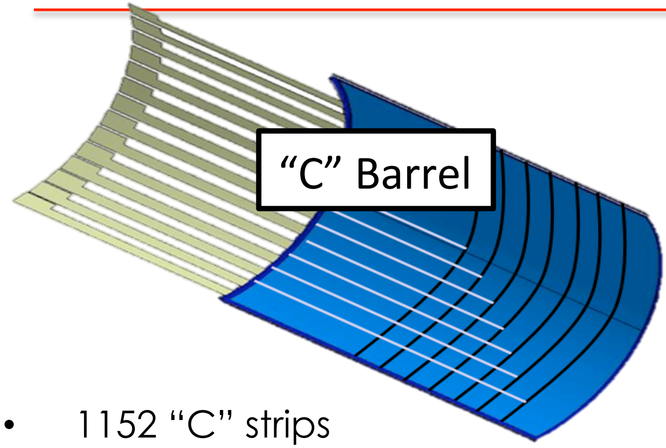


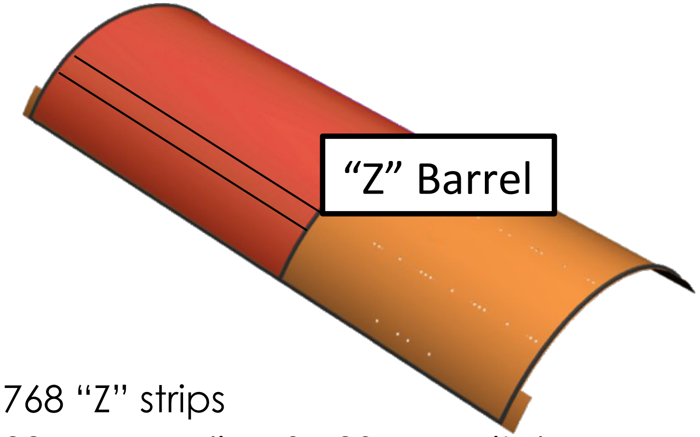
Charging effect measurement using X-Rays



>98% efficiency, ~60µm res., 18ns time res.

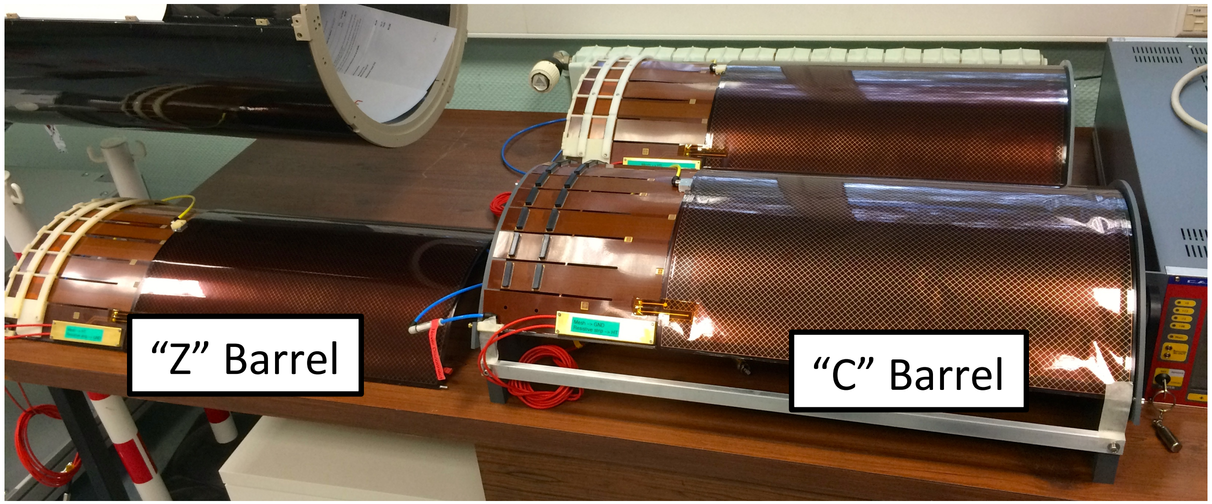
CLAS12 Barrel

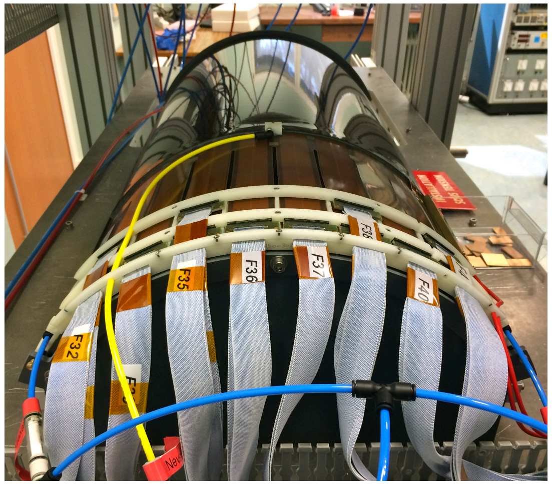




- 1152 "C" strips
- Pitch from 0.67 to 0.33 mm
- 221 mm radius
- PCB thickness 100 μm
- Drift thickness 250 μm
- Drift Field 2.4kV on 3 mm gap

- 768 "Z" strips
- 225 mm radius, 0.529 mm pitch
- PCB thickness 200 μm
- Drift thickness 250 μm
- Drift Field 2.4kV on 3 mm gap
- 0.37% of X0

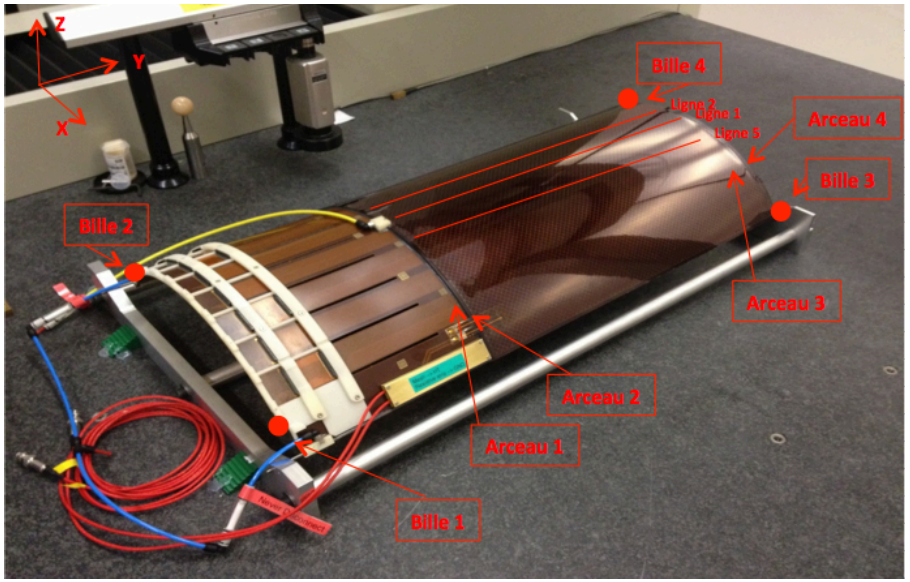


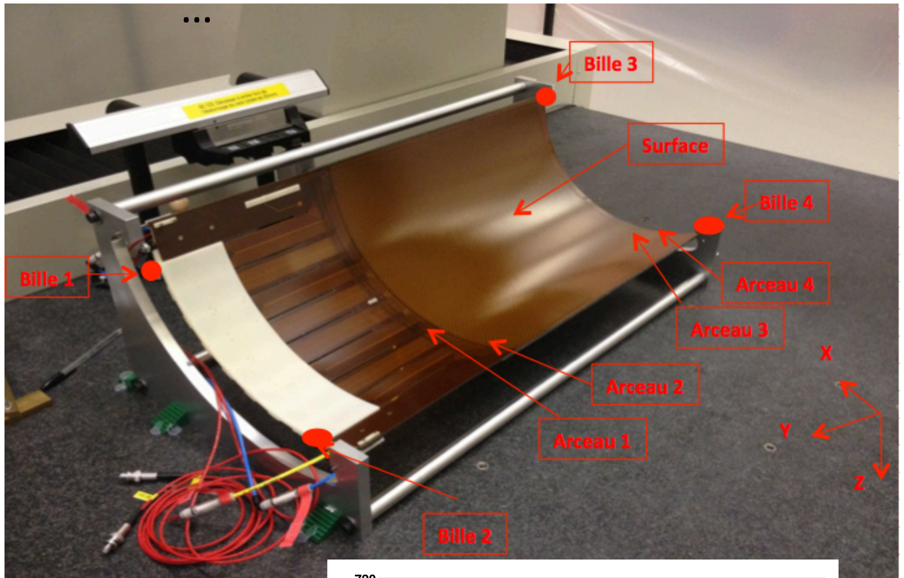


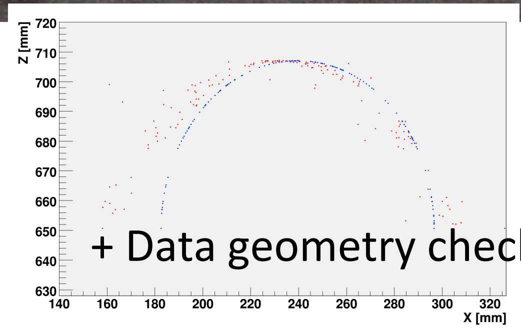
CLAS12 Barrel : Geometry

- 3D probing machine measuring points :
  - 270 points on top (drift side)
  - 120 points under (readout side)

List of measured points			
	X	Y	Z
PT-Arceau1_1	-3.588	231.995	-0.005
PT-Arceau1_2	28.993	231.995	33.071
PT-Arceau1_3	64.992	231.994	57.126

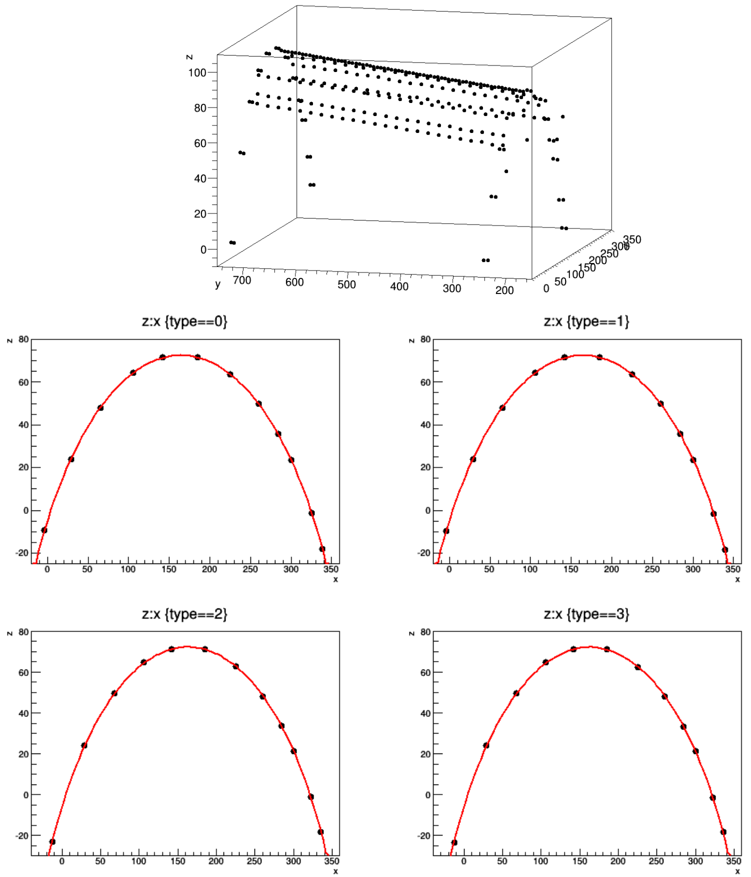


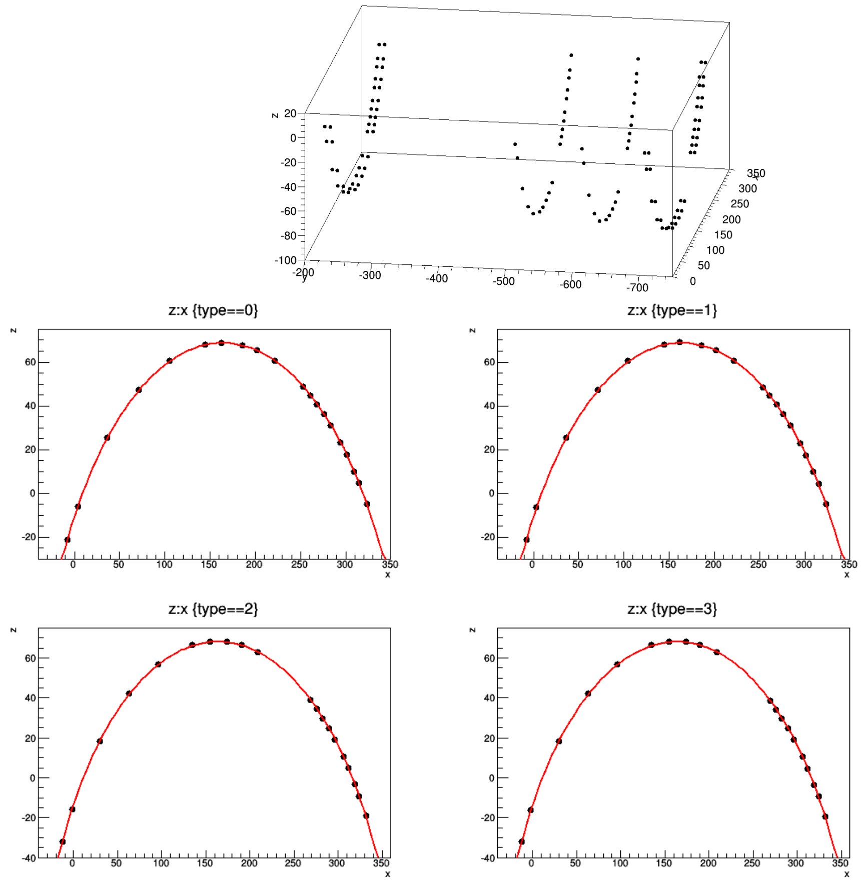




+ Data geometry check

CLAS12 Barrel : Geometry



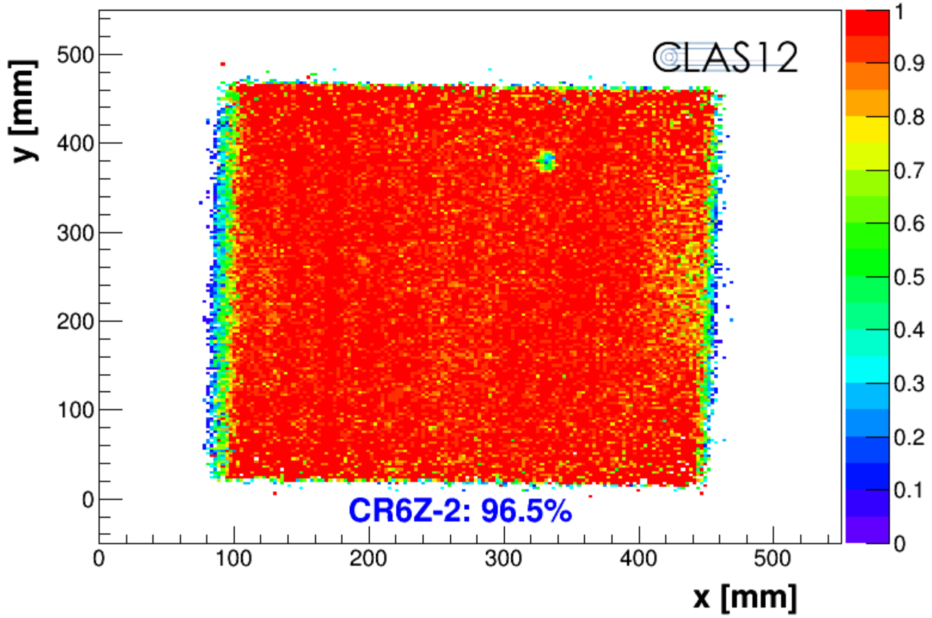


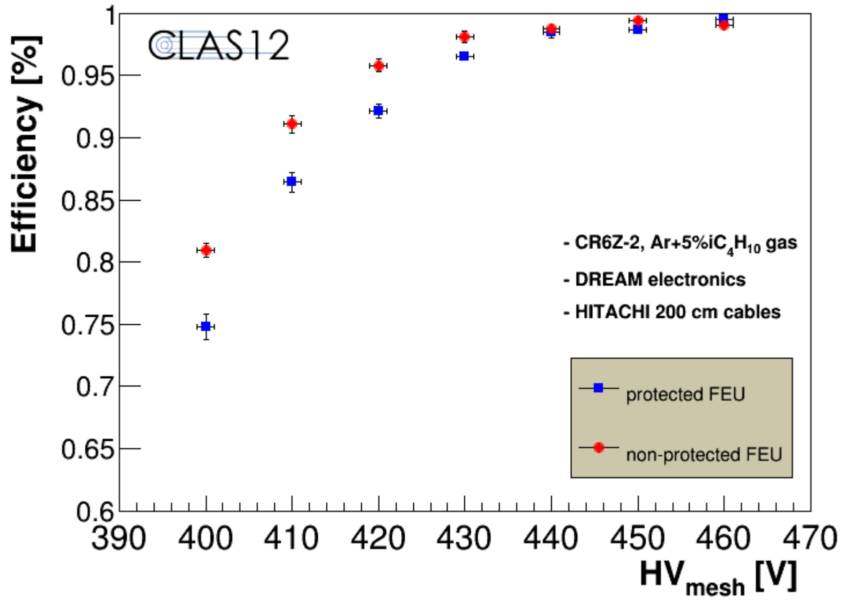
OUTER (4 Arceaux)
X0 = 163.6 +/- 0.6
Z0 = -138.9 +/- 1.6
R= 211.3 +/- 1.8

INNER(4 Arceaux)
X0 = 163.8 +/- 1.8
Z0 = -138.9 +/- 1.9
R= 207.3+/- 2.1

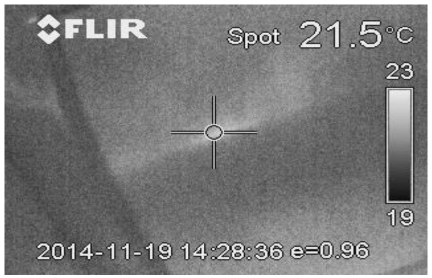
=> Cylindrical geometry precision up to ~2mm in radius

CLAS12 Barrel Z : Performances

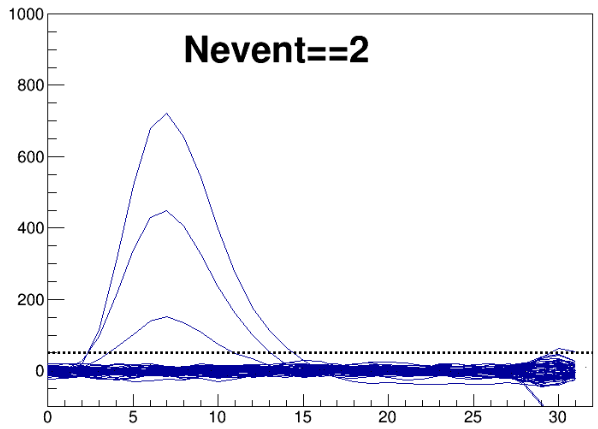




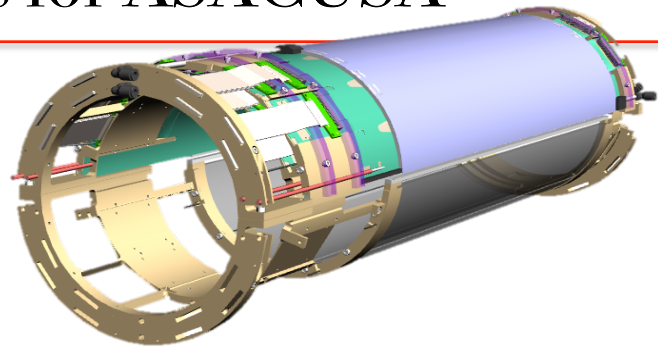
After default isolation using IR camera !



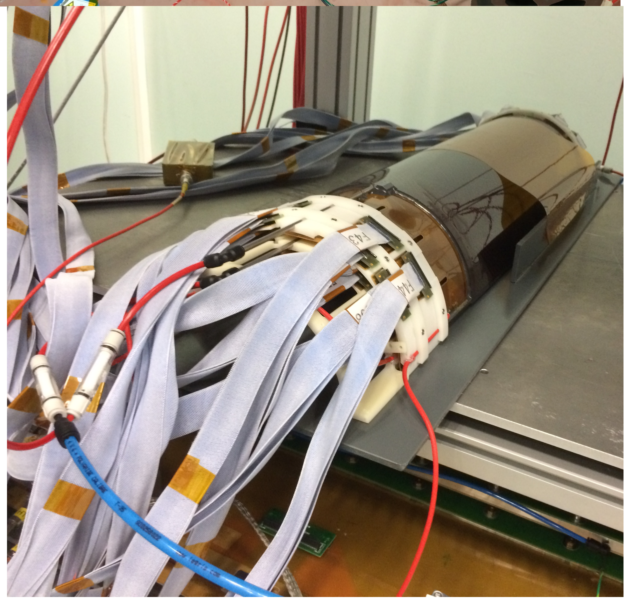
Zoom on a part of the CLAS12 Barrel pre-series #2 with thermal cam, with HV on and current of about 300 μA

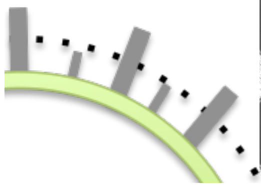


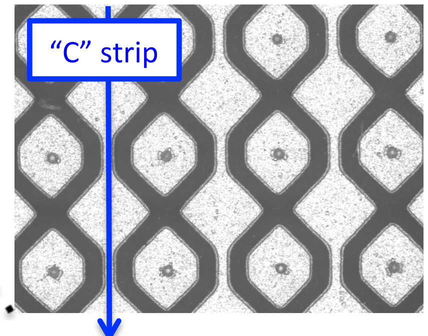
Small Radius Barrel Detectors for ASACUSA



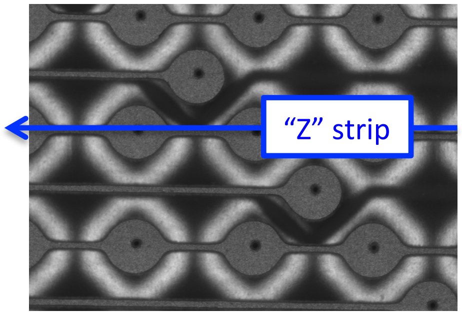
- Tracker for anti-Hydrogen experiment.
- 2D metallic Micromegas
- Internal Layer R_{MIN} : 60cm x 85 mm radius
- External Layer R_{MAX} : 60cm x 95 mm radius
- Intermediate support pillars
- DREAM electronics (deported)
- MEC8 connectors and Hitachi cables from CLAS12
- 3D printed structure (white)
- Cutout flaps for a better deformation at the connector level
- Gas distribution through aluminum frame
- 0.87mm pitch: 250 longitudinal Z strips, 500 circulars C strips
- 4T magnetic field







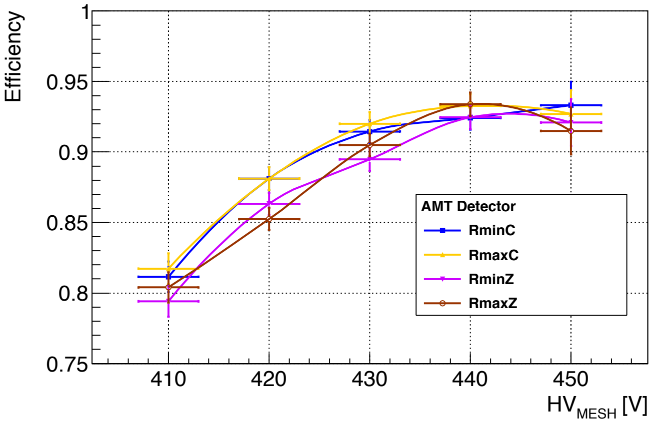
Readout pattern (top)

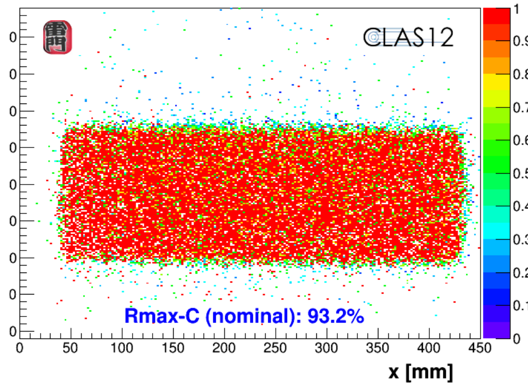


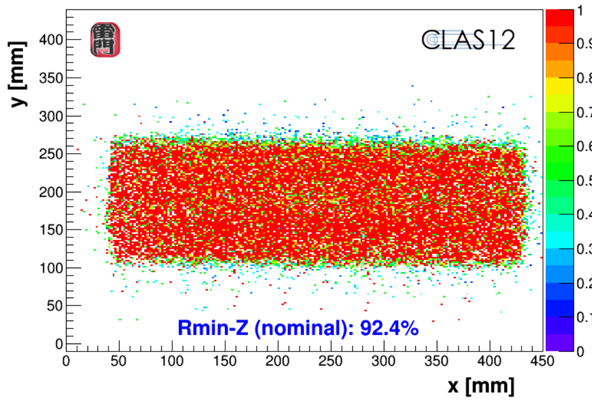
Readout pattern (bot)

Small Radius Barrel Detectors for ASACUSA

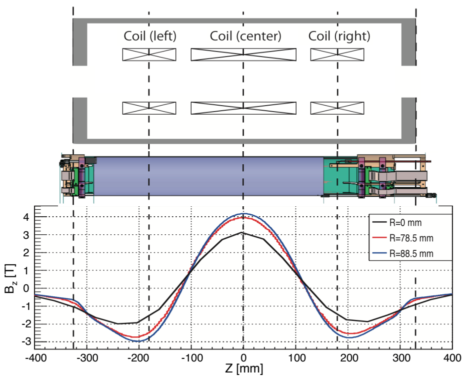
- Characterization at Saclay :

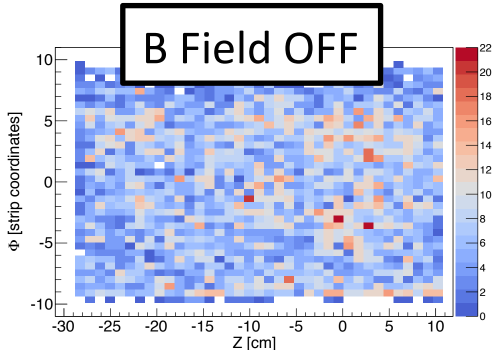


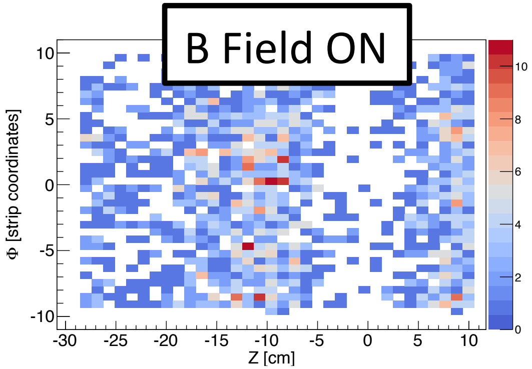




- 6 Months of smooth data taking ! (technical paper submitted)
- Effect of the magnetic field

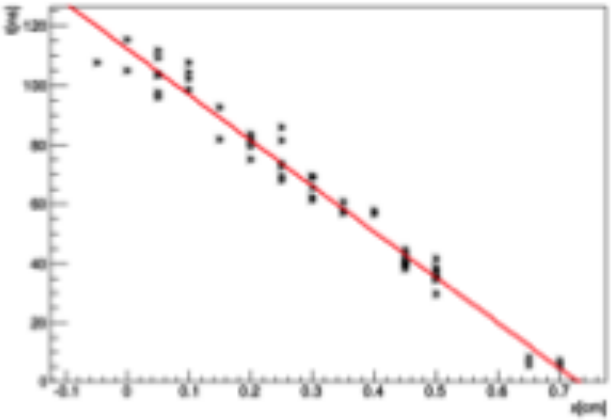


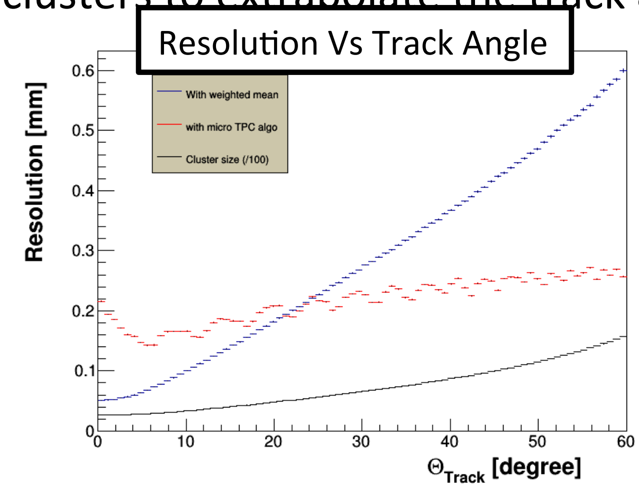




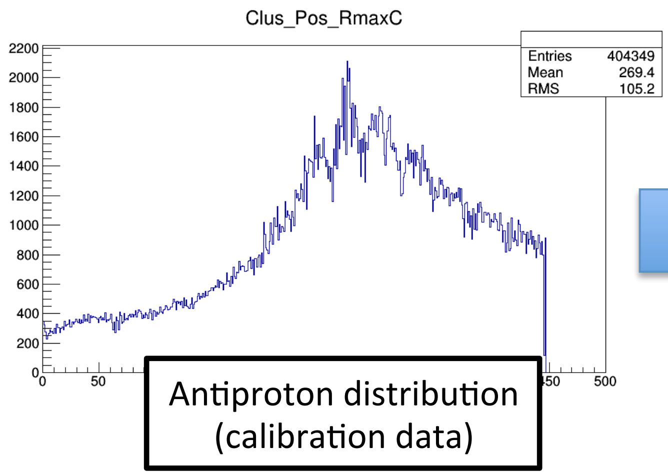
ASACUSA – MicroTPC

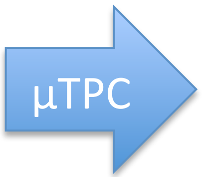
- MicroTPC algo uses the time info on multi-strip clusters to extrapolate the track angle

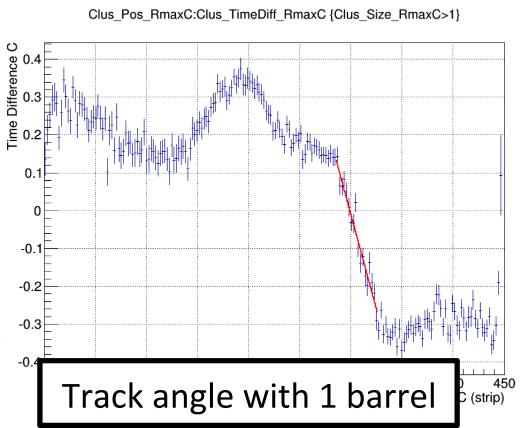


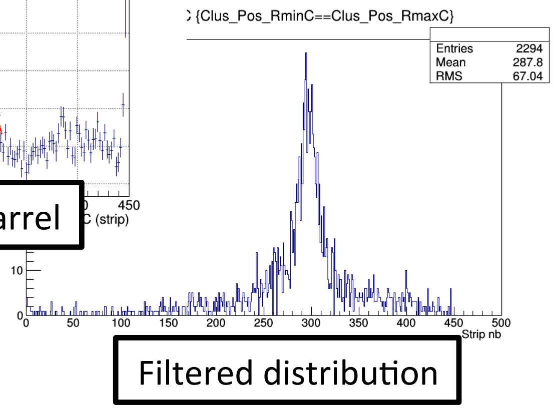


- MicroTPC algo on physics data :









Conclusion

- The Micromegas technology has evolved a lot since 1996
- Recent R&D focused on cylindrical chambers, resistive readout, spark reduction technology and high-rate/low material detectors
- The DREAM based has proved to be fully functional and not too hard to use
- Cosmic rays test bench shared facility at Saclay has been extensively use this last year
- Production, assembly, and full characterization of :
  - MINOS TPC (2)
  - Pixel MM for COMPASS II (6)
  - Forward Det. For Clas12 (4)
  - Barrel for Clas12 (2Z, 2C)
  - GMT for Gbar (4)
  - AMT for ASACUSA (5)
  - Forward Tagger for CLAS12 (1)
  - MultiGen for M^3 and Watto (5)

- **Outlook :**
  - End of production / assembly for CLAS12
  - Installation of the central tracker this summer at Jlab
  - Muon Tomography experiment ongoing
  - New run for ASACUSA
  - DREAM Adaptation for the FGT

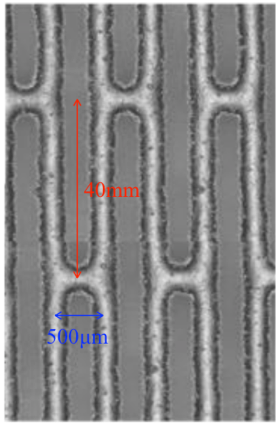
  - Ready for new challenges !

Spares

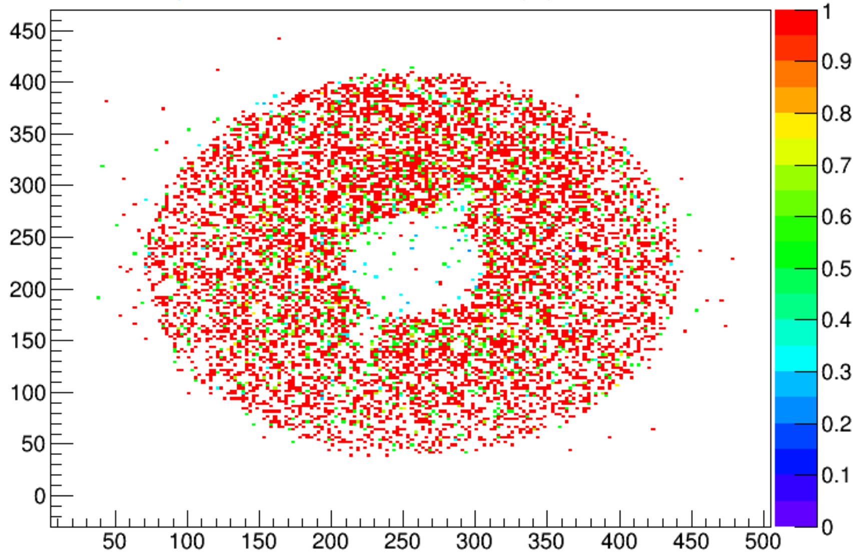
Forward disk for CLAS12: issue with resistive ladders

- 2 pre-production detector tested, One not ok :
  - High current due to a contact in the active area (can't burn it with sparks)
  - Large impacted zone due to ladders
  - Drift electrode glued

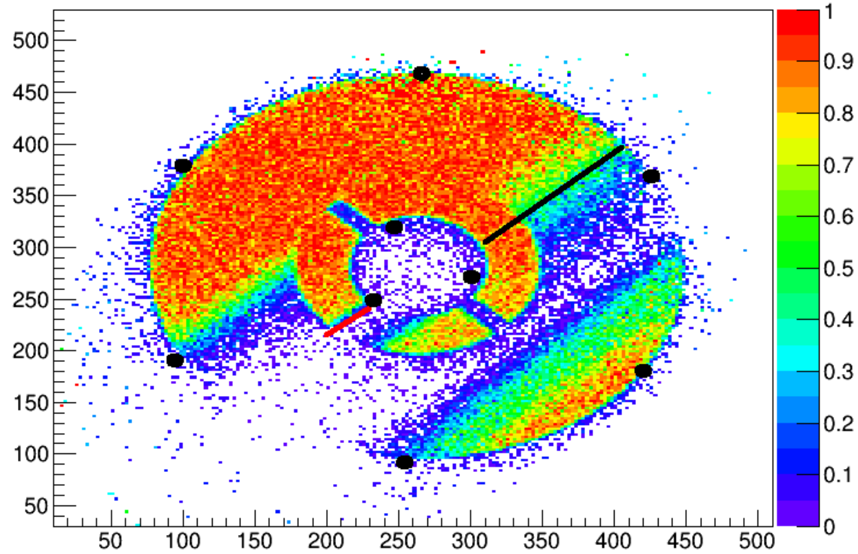
⇒ Production detectors
  - ⇒ No ladders
  - ⇒ Re-openable design with screws



Before the current appeared



With current

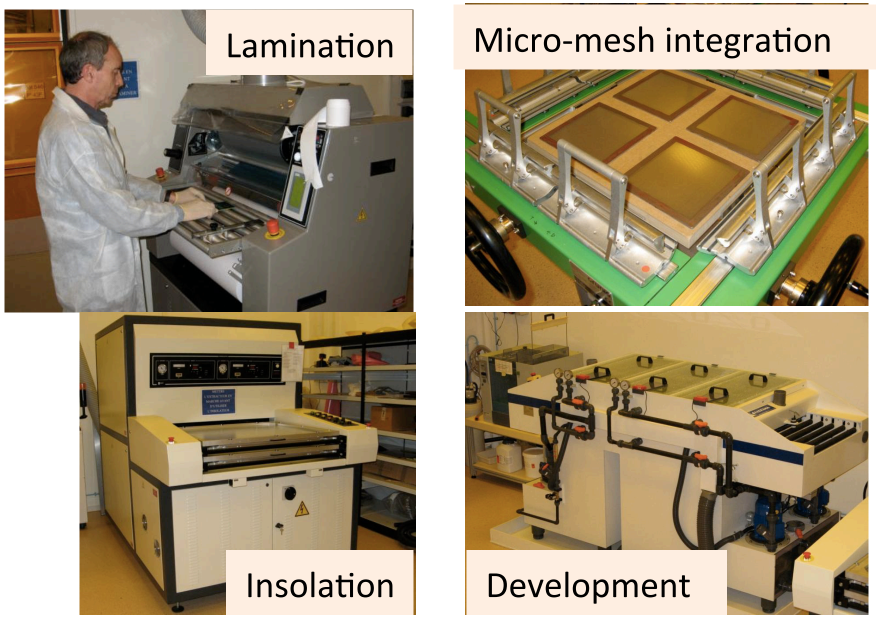


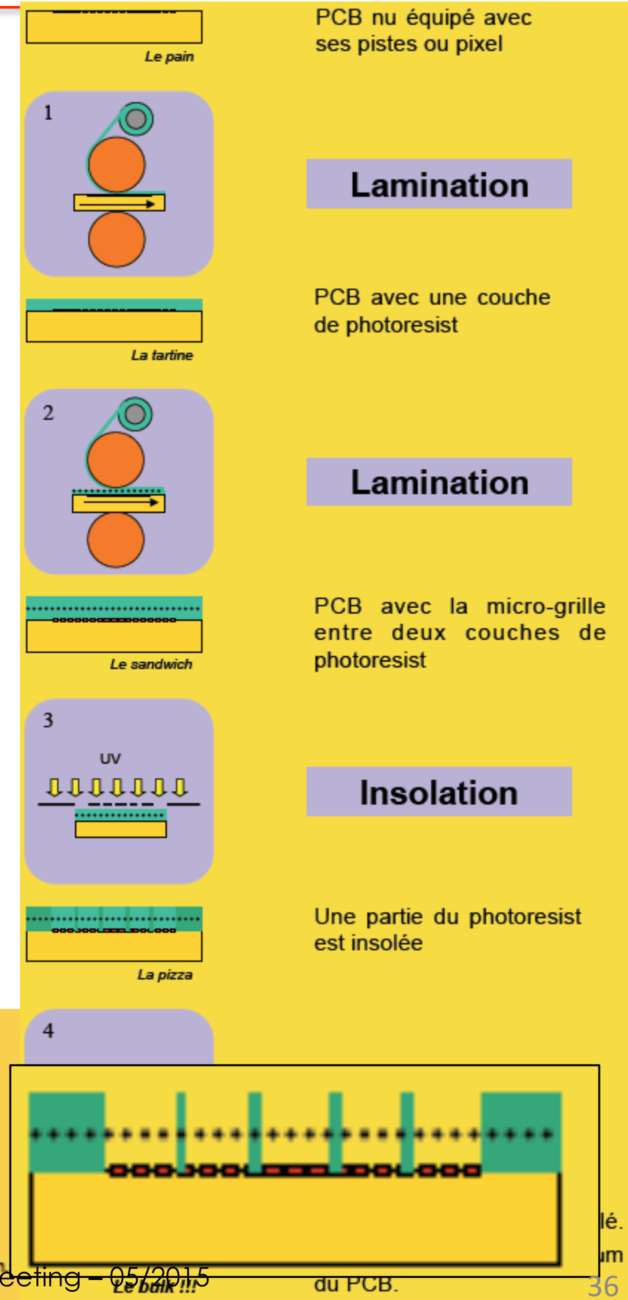
⇒ unefficiency regions are determined by the position of the contacts to the resistive film

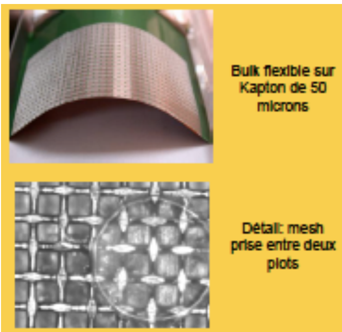
Bulk Micromegas : Fabrication scheme

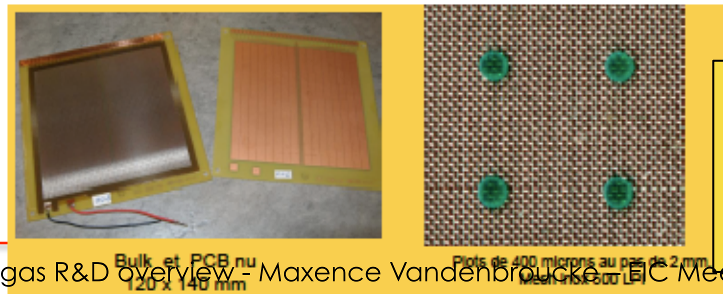
- First prototypes in 2004. Collaboration CERN/Irfu.
- The woven micro-mesh is laminated between two photo-sensitive layers → reduction of dead zones
- Large areas
- Robust, industrial process (printed circuit)

BULK workshop at Irfu/Sedi

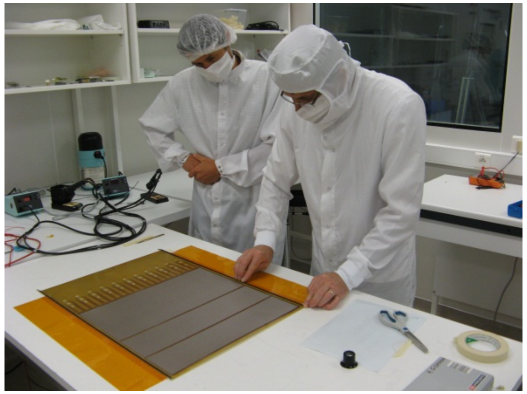




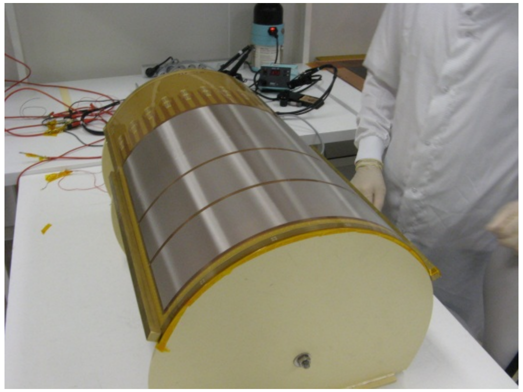




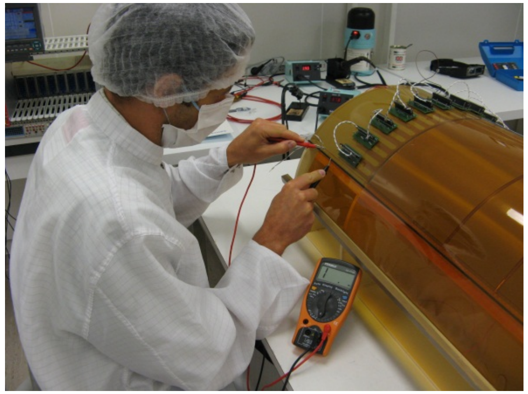
Curved Micromegas : Fabrication process



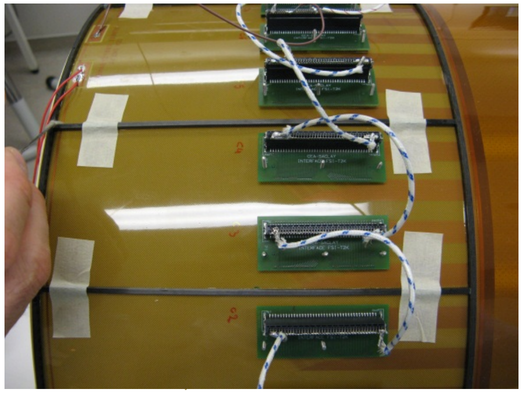
Segmentation and preparation



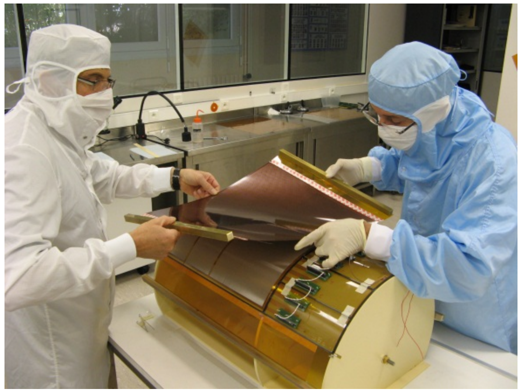
Gluing of the side carbon ribs on circular shape

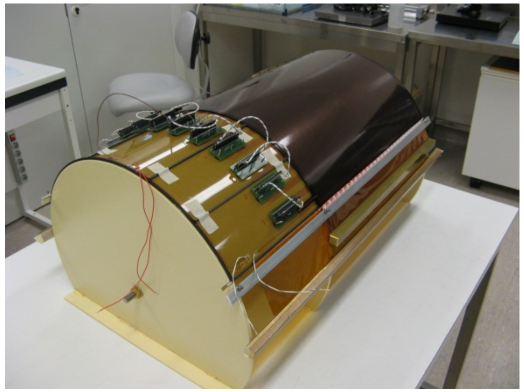


Electric leak test



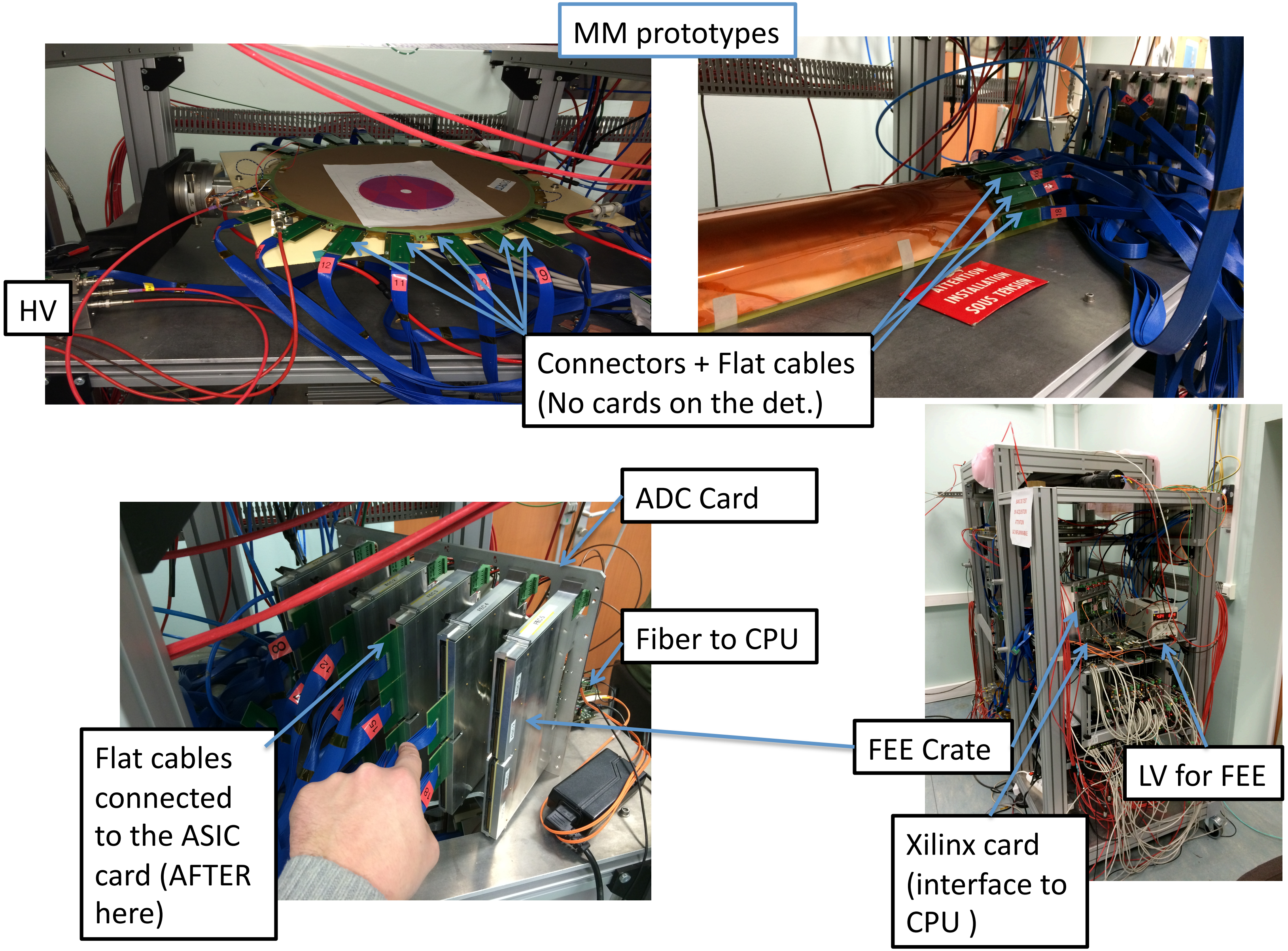
Gluing of additional ribs





Setting and gluing of drift plane

Test Bench DAQ – AFTER



AGET FEMINOS

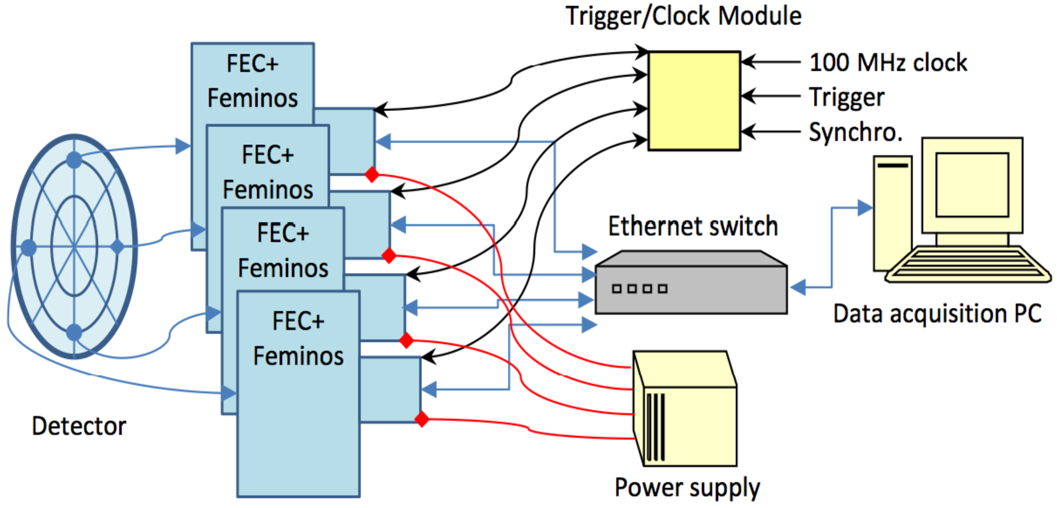
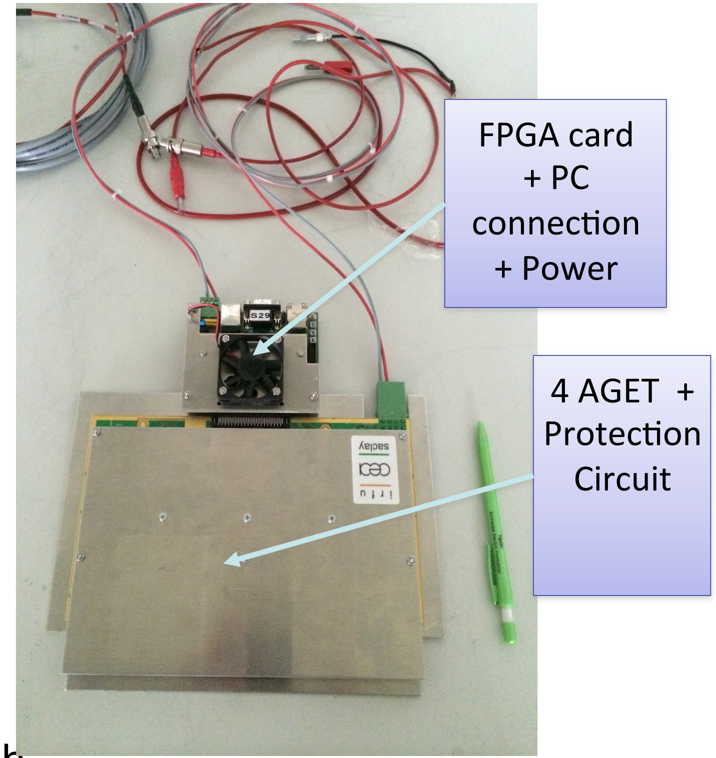


Fig. 1. Feminos application example.



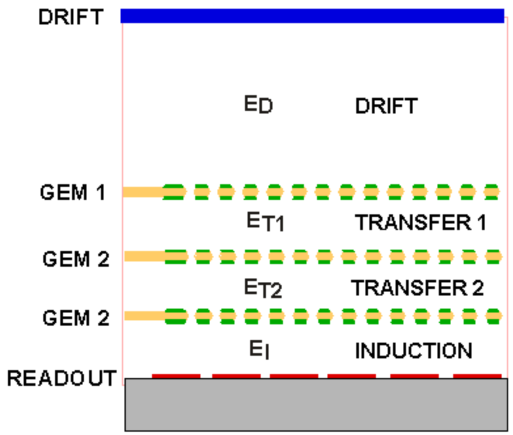
One FEC FEMINOS

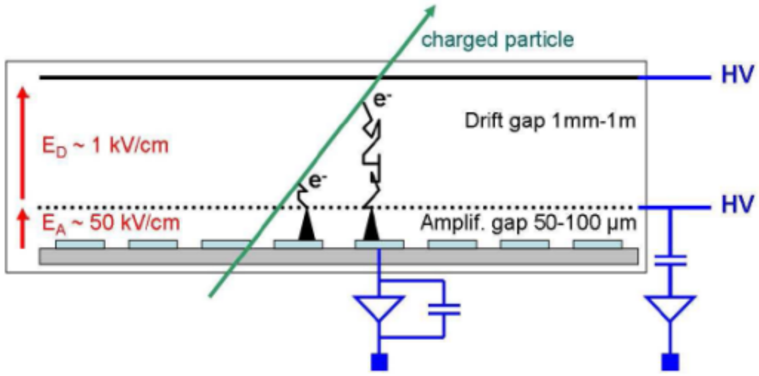
- 4 AGET per Front-End Card (FEC) 4x64 = 256 channels
- 1 FEC can run in stand alone mode
- Up to 24 FECs with a Trigger Clock Module (TCM) 6144 ch.
- Connection to PC via 1Gbit Ethernet (RJ45)
- TCM card able to deal with internal and external trigger

AGET vs. DREAM - Notes

- About Zero suppression, CM noise suppression, etc… both systems has these functionalities and more implemented in the control FPGA. (it is also possible to do everything offline of course)
- Readout software exists in both case at different level of development, but they work
- Slowcontrol software is ok too
- Protection circuit : Micromegas-like one, possible to remove it but very dangerous.
- **Connection to the detector :**
  - Both ASICs are not on the detector but connected via cables
  - It is possible to make cards like the APV one but it has to developed.
  - DREAM existing cables use MEC8 connector
  - AGET uses ERNI on the FEC side (? on the detector side)
- Power cables/supply : standard 12V, nothing particular
- Acquisition architecture, see next slides

GEMs vs. Micromegas





- Multiplication in the holes
- ~ 50% of electrons transferred
- Gain per layer a few 10's to 10^3
- Low ion back flow (1%)
- Multistage structure → gain 10^5
- More fragile and more integration issues

- Multiplication between mesh and anode
- Stability of gain wrt gap
- Gain 10^4-10^5
- Low ion back flow (1%, down to 10^{-6})
- Robust
- Sparking unless resistive or preceded by a GEM foil for preamplification
- Smaller ultimate thickness (both in mm and X_0)
- Slightly more radiation resistant

FEE R&D for New Proposal

- DREAM parameter

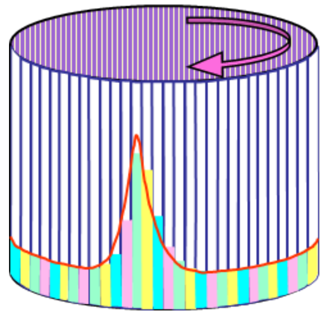
Parameter	Value
Polarity of detector signal	Negative or Positive
Number of channels	64
External Preamplifier option	Yes, access to the filter or SCA inputs
Charge measurement	
Input dynamic range/gain	50 fC; 100 fC; 200 fC; 600 fC, selectable per channel
Output dynamic range	2V p-p
I.N.L	< 2%
Charge Resolution	> 8 bits
Sampling	
Peaking time value	50 ns to 900 ns (16 values)
Number of SCA Time bins	512
Sampling Frequency (*WCk*)	1 MHz to 50 MHz
Triggering	
Discriminator solution	Leading edge
HIT signal	OR of the 64 discriminator outputs in LVDS level
Threshold Range	5% or 17.5% of the input dynamic range
I.N.L	< 5%
Threshold value	(7-bit + polarity bit) DAC common to all channels
Minimum threshold value	≥ noise
Readout	
Readout frequency	Up to 20 MHz
Channel Readout mode	all channels excepted those disabled (statically)
SCA cell Readout mode	Triggered columns only
Test	
Calibration (current input mode)	1 channel among 64; external test capacitor
Test (voltage input mode)	1 channel among 64; internal test capacitor (1/charge range)
Functional (voltage input mode)	1, few or 64 channels; internal test capacitor/channel
Trigger rate	Up to 20kHz (4 samples read/trigger).
Counting rate	< 50 kHz / channel
Power consumption	< 10 mW / channel

Table 1: Summary of the DREAM requirements.

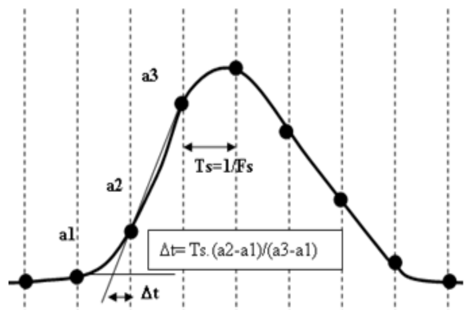
D
P

DREAM (Dead-timeless Read-out Electronics ASIC for Micromegas)

- Signals are continuously pre-amplified, shaped, sampled at 20-30 MHz and kept in the circular analog memory
  - Deep enough to sustain 16 μs trigger latency



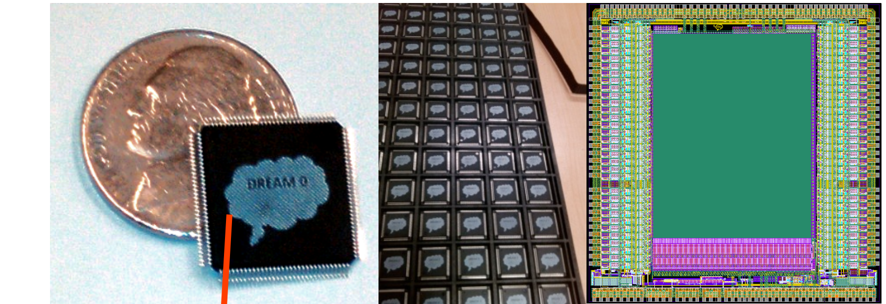
- At each trigger 4 - 6 corresponding samples are readout and digitized
  - Readout does not disturb sampling
- Retained samples are digitally processed
  - Pedestal equalization – online
  - Common noise subtraction – online
  - Zero suppression – online
  - Measure charge and time – off-line

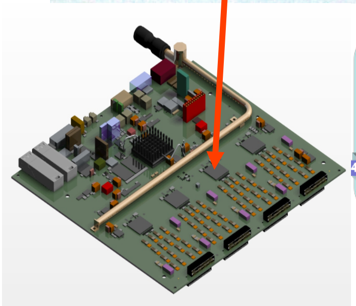


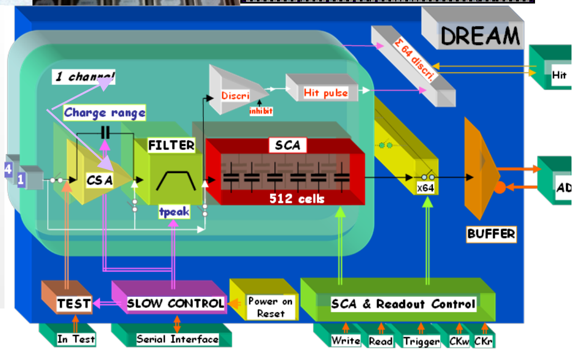
Courtesy: E. Delagnes

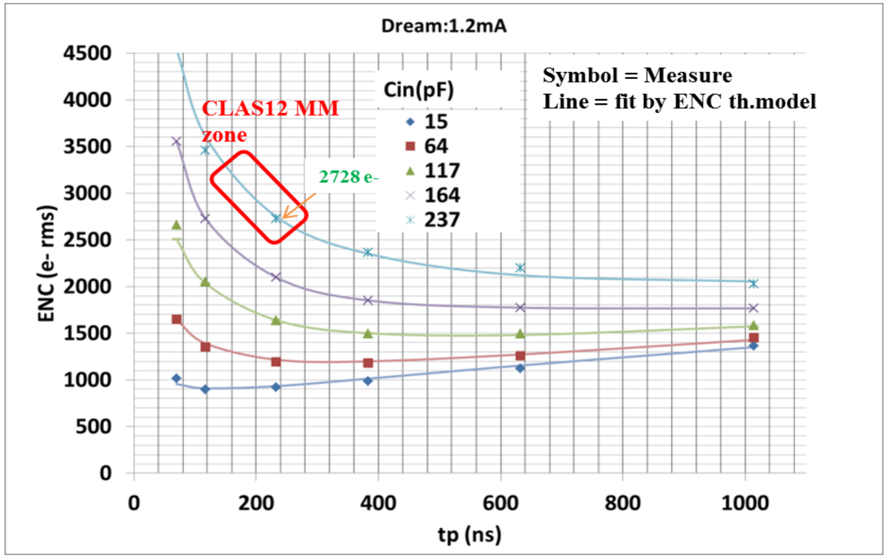
DREAM chip

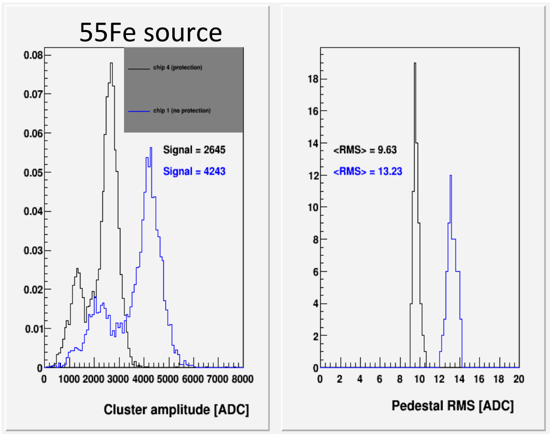
- Tailored for detectors with high capacitances
  - ~30% less noise compared to the previous generation (after ASIC)
  - Depending on detector type ENC of 2000-2700 is expected
- Version 1 submitted
  - Added intermediate peaking times for more flexibility
  - Minor bugs corrected
  - Packaged chips expected in May-June







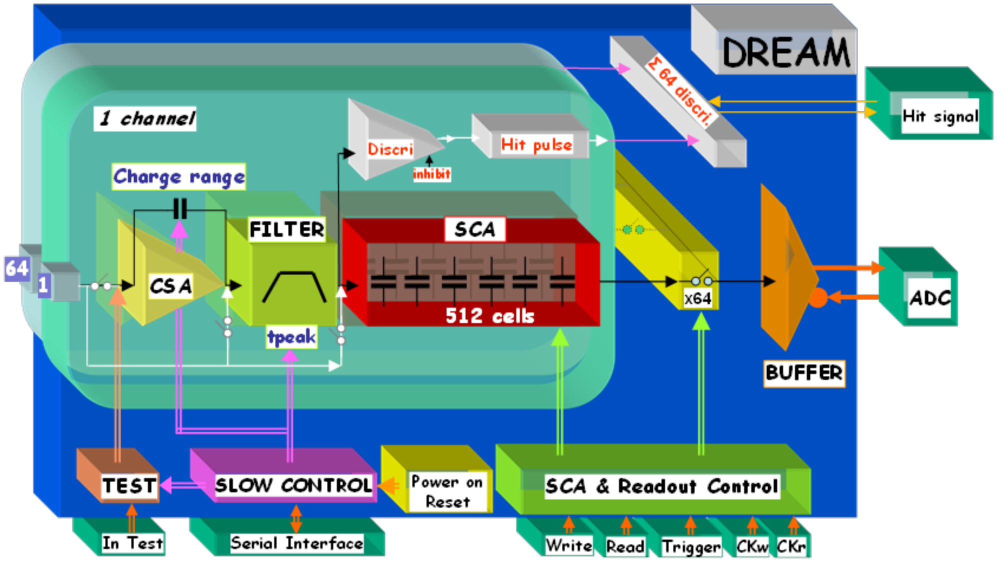




Front End Unit : Active comp. on top & bottom sides

- 8 Dream ASICs
- 8-channel 40 MHz ADC
- Virtex-6 FPGA
- SFP cages
  - 2.5 Gbit/s optical link
  - 1Gb Ethernet
- JTAG based system monitor

DREAM-based electronics

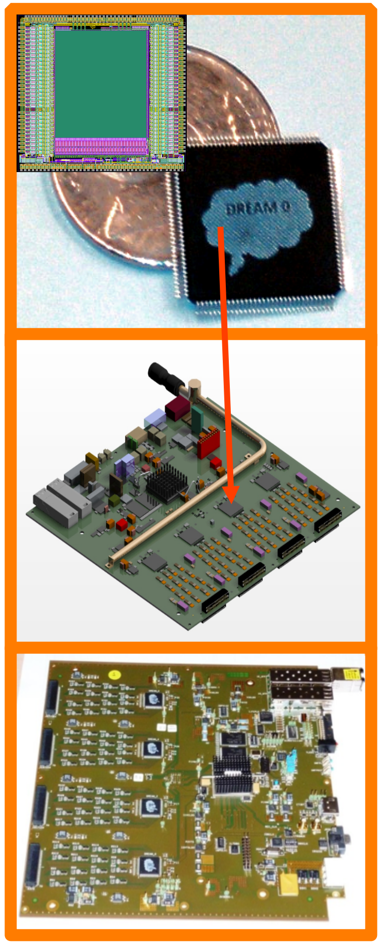


- Evolution of AFTER and APV25 chips
- Tailored for high capacitance detectors (MPGDs)
- Dead-time free
- Low noise : 2100e-

- v0 chip validated in 2012
- Sample of v1 chip received summer 2013
- Full production of final revision in March 2014

- Gain in S/N up to 25% wrt previous chip generation
- Self-triggering capabilities (part of EIC R&D, successfully tested !)

- Front-end unit prototype received, tested, validated. 12 boards ordered (6000 channels)
- Production of 70 units for 2014 (part of which is for this proposal)



First front-end prototype

64-channel Dream ASIC Dead-timeless Read-out Electronics ASIC for Micromegas

- Characteristics
  - 4 gain ranges: 60 fC, 120 fC, 240 fC, 1 pC
- 16 programmable peaking times: from 50 ns à 1 μs
- Sampling rate: 1- 50 MHz
- • 512-cell deep analog memory per channel
  - Trigger pipeline of 16 μs + derandomizing
- • Readout rate: 20 (40) MHz
- • 140-pin 0.4 mm package
  - Small 17 mm x 17 mm footprint
- • Adapted for different detector types

GEMs vs. Micromegas (2)

GEM: Sauli 1997

- COMPASS
- LHCb muon detector
- TOTEM telescope
- HBD (Hadron Blind Detector)
- NA49 (upgrade)
- X-ray polarimeter (XEUS)
- GEM TPC for LEGS, BONUS
- STAR FGT
- KLOE2 vertex detector
- OLYMPUS
- SuperBigBite (JLab/Hall A)
- CMS forward muon chambers
- ……

and at the proposal/prototyping stage

- EIC R&D
- DarkLight phase-I
- …..

MM: Giomataris 1996

- COMPASS (1 & 2)
- NA48/KABES
- CAST (CERN Axial Solar Telescope)
- nTOF (neutron beam profile)
- Piccolo (in reactor core neutron measurement)
- T2K TPC
- JLab/CLAS12/MVT
- RIKEN/MINOS (exotic nuclei spectroscopy)
- ATLAS muon system upgrade
- …..

and at the proposal/prototyping stage

- ASACUSA (anti-H)
- HARPO (astrophysics)
- MIMAC (dark matter)
- FIDIAS & ACTAR (low-energy heavy ion)
- EIC R&D

CLAS12 Operating Conditions

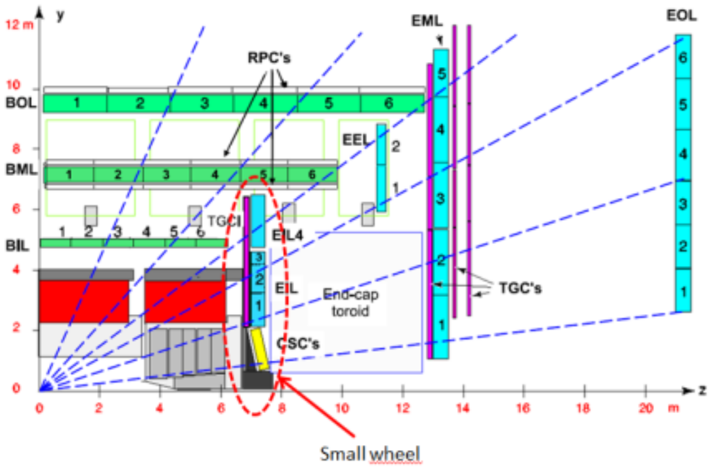
Parameter	Barrel MVT	Forward MVT
Effective Gain	5000	3000
Gas mixture	Ar + 10% iC_4H_{10}	Ne + 10% C_2H_6
Conversion gap	3 mm	5 mm
Drift field	8 kV/cm (Z) et 4 kV/cm (C)	1 kV/cm
Lorentz Angle	20° (Z) et 40° (C)	0°
Fields ratio	5,5 (Z) et 9 (C)	~ 50
Transparency	40% (Z) et 50% (C)	100%
X_0	0,3%	0,3%
Segmentation	Longitudinal in 3 parts	Annular in 3 parts
Maximum PCB size (capacitance)	45x43 cm² (16 nF / 3)	Φ 43 cm (12 nF / 3)
Particle rate / layer	4 MHz (incl. 1 MHz hadrons)	12 MHz (incl. 2 MHz hadrons)
Discharge rate/ mesh	1 Hz	1 Hz
Deadtime	< 2 %	< 2%
Detection efficiency	> 90%	> 95%
Pitch	540 µm (Z) et 270 µm (C)	500 µm
Spatial resolution	250 µm (Z) et 100 µm (C)	145 µm
Time resolution	10 ns	10 ns

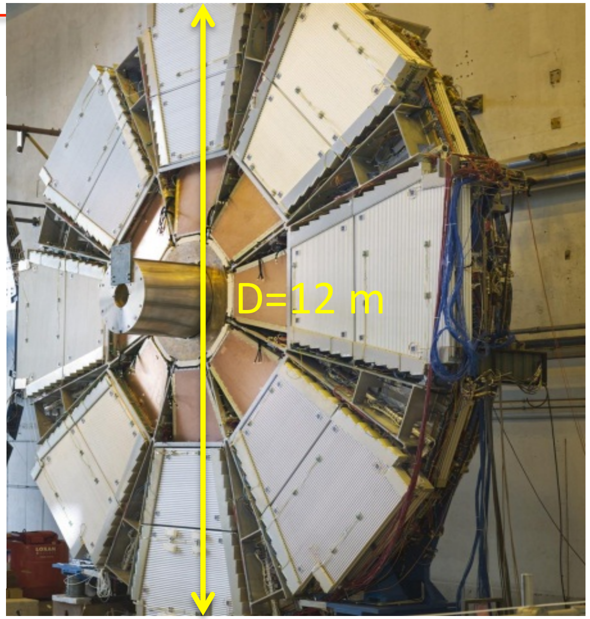
ATLAS Micromegas small wheel project

ATLAS/NSW

2 new wheels (NSW):

- 1200 m² of resistive Micromegas
- More than 2M electronics channels



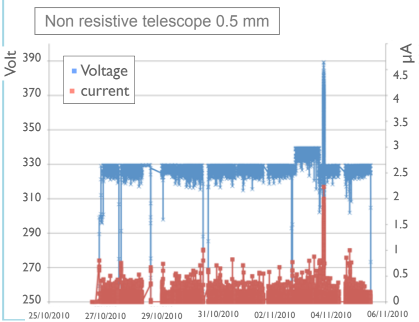


High flux et sparking

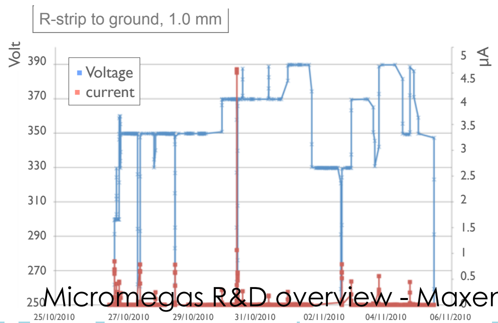
Resistive anodes:

- Reduced spark amplitude
- No dead time
- Robustness

Non resistive



Resistive

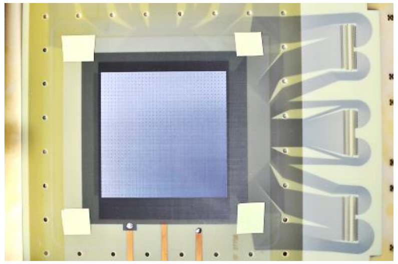


Fabrication

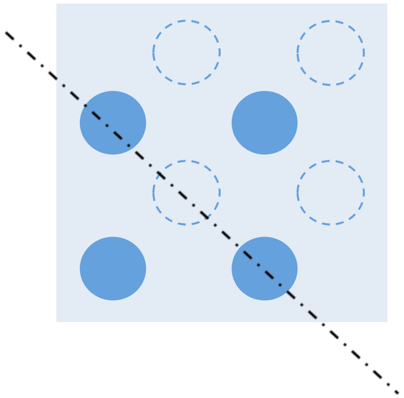
- Maximum area ~ 2 m²
- Production: 1024 planes (2015-16)

Transfer to industry:

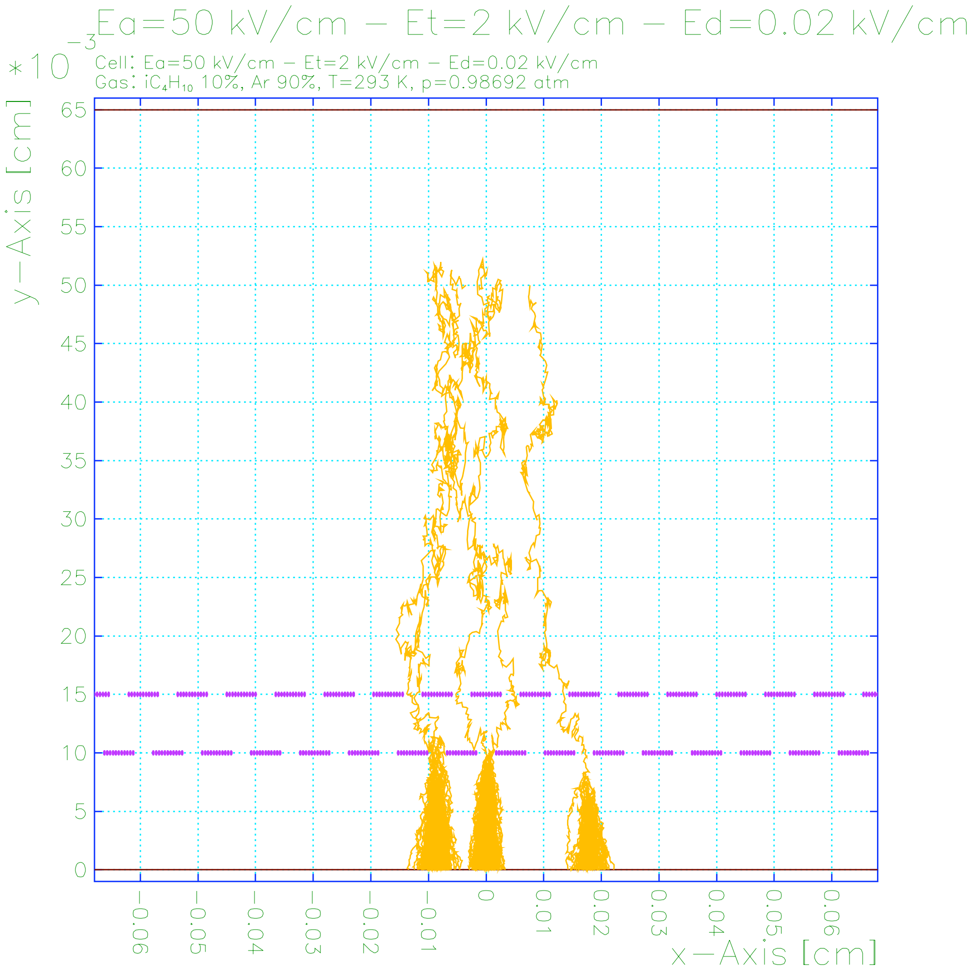
- ELVIA (France)
- ELTOS (Italy)
- Triangle Labs (US)



Double-mesh simulations



- comparison with measurements
- Transparency vs amplification gap
- Transparency vs transfer gap
- IFB vs amplification gap
- IFB vs transfer gap



Performed with GARFIELD

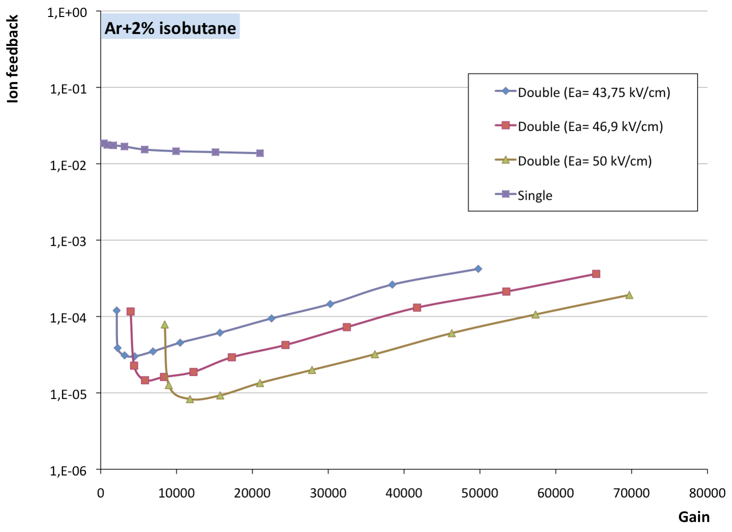
FGT Disk setup

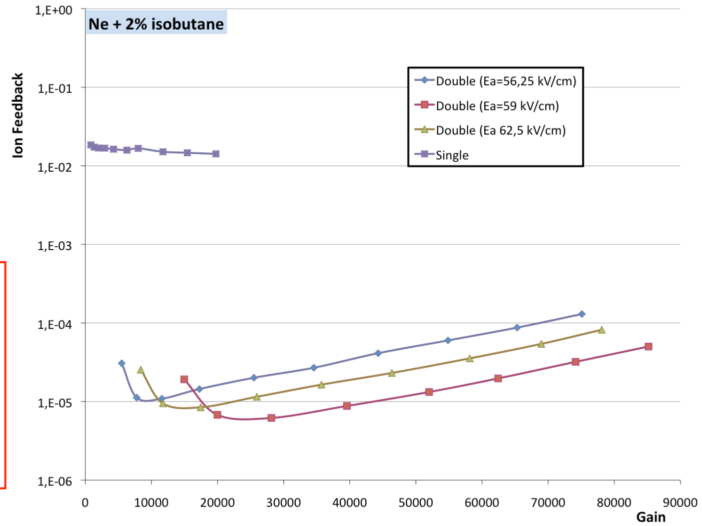
- DREAM :
  - Pros :
    - Better than AGET with large detector (including cable) capacitance
    - Suitable for trigger rate >1kHz
    - Possibility to run with a threshold to issue a trigger (one threshold per ASIC)
    - Used by CLAS12 (Jlab compatibility will be developed)
  - Cons :
    - All channels are always read when a trigger is issued
    - 40Mhz sampling frequency max
- AGET :
  - Pros :
    - Fancy trigger possibilities : one threshold per channel, Multiplicity information available at the ASIC stage
    - Possibility to readout only channels with signal
    - 100MHz sampling frequency max.
  - Cons :

DREAM CHIP FrontEnd
Philadelphia, PA, June 04, 2014

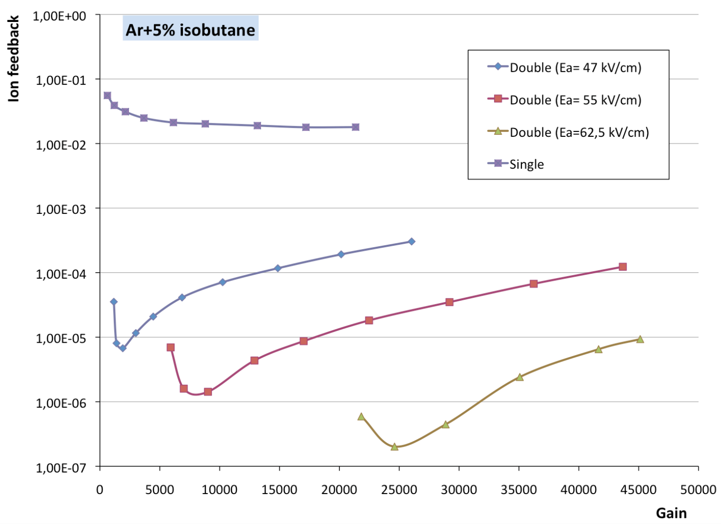
    - Small det. Capa.
    - Suitable for trigger rate <1kHz

Double-mesh ion gate mode

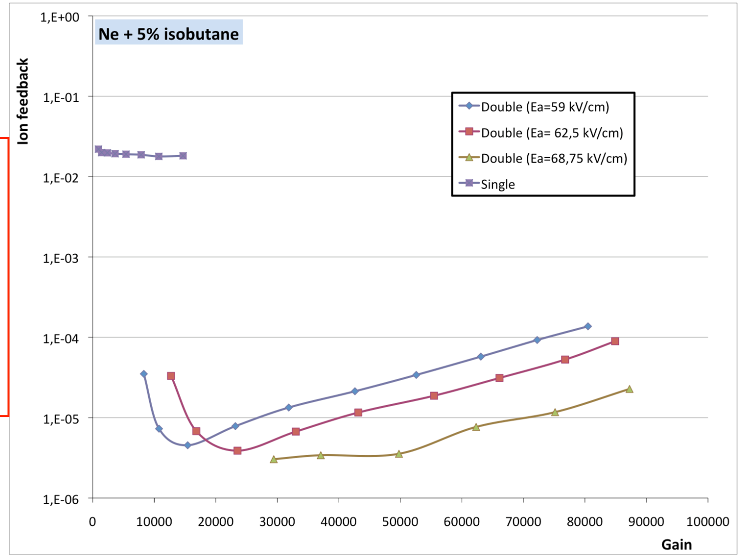




Double mesh gating decreases the ion back-flow of at least 2 orders of magnitude



The ion feedback is increasing as the transfert gap contribute to the total gain

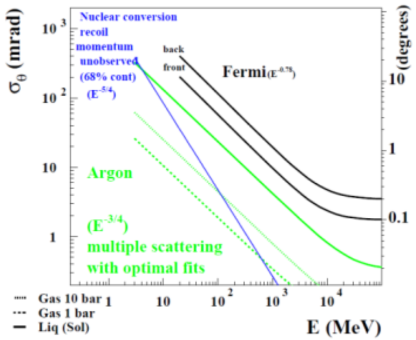


THE HARPO (HERMETIC ARGON POLARIMETER) PROJECT

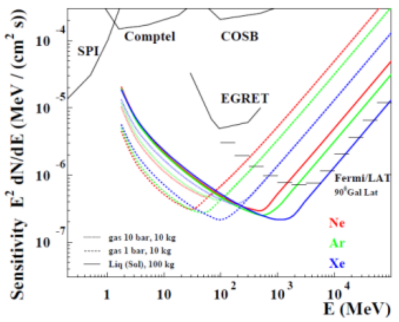
- Motivations: no γ-polarimeter sensitive above 1 MeV in space astronomy
  - Comology/New Physics: search for Lorentz Invariance Violation (LIV) sensitivity $\propto E^2$
  - Astrophysics: understand mechanic(s) in γ cosmic sources
- Instrumental method:
  - Use a Time Projection Chamber for Pair Production ($\gamma Z \rightarrow Z e^- e^+$) & Triplet Production ($\gamma e \rightarrow e^- e^+ e^-$)
  - 3D reconstruction in a "thin" homogeneous pressurized argon-based gas mixture
- Innovation: new high-resolution & high sensitivity way to perform MeV-GeV γ-ray astronomy & for the first time polarimetry

Simulations

- Angular resolution

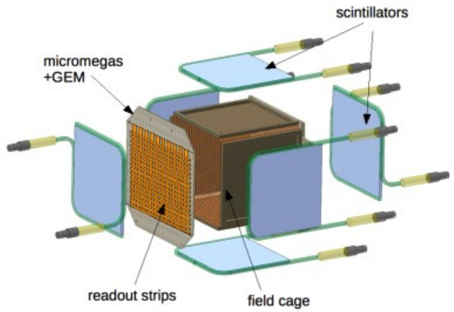


- Point-source differential sensitivity in 3 years

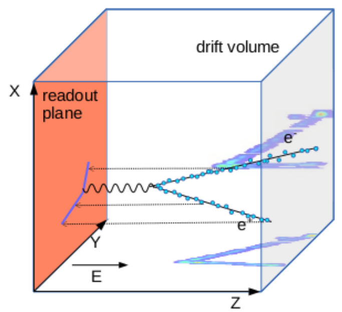


Demonstrator

- Micro-Patterned Gas Detector triggered by plastic scintillators



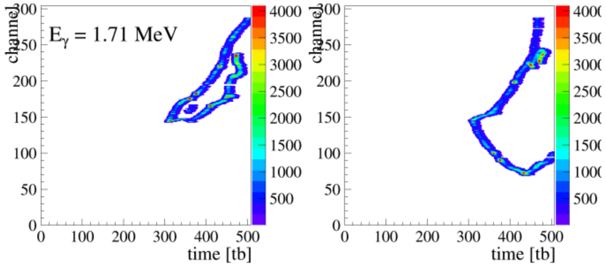
- Cubic detector with 2×1D (x,y)+z readout for 3D tracking



Polarized γ beam test

- Newsubaru (Japan), November 2014

- Candidates of γ conversion in gas mixture

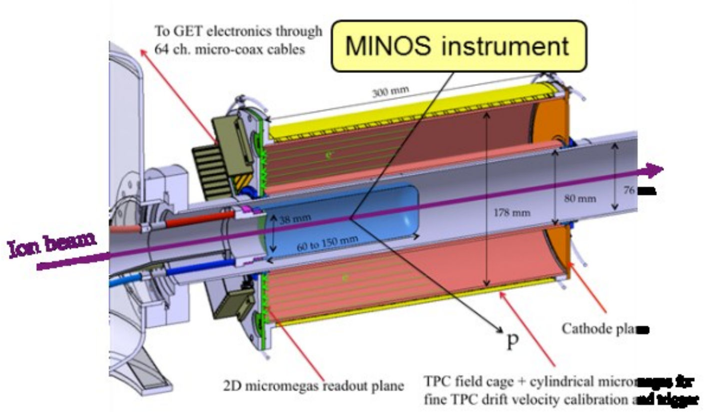


Data analysis is in progress

MINOS: A CYLINDRICAL TPC FOR THE STUDY OF EXOTIC NUCLEI (RIKEN, JAPAN)

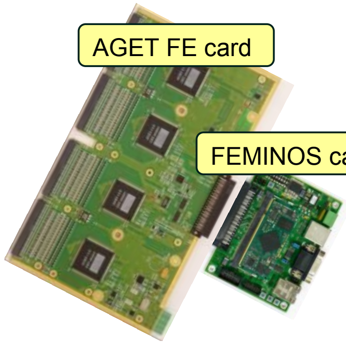
Minos innovation

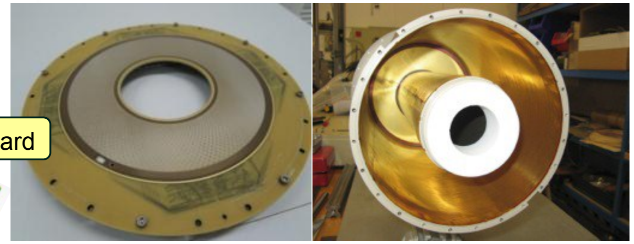
- Improve energy resolution for γ spectroscopy of knock-out reactions in thick target by using a TPC to localize the vertex.



Instrument design : 2010-2014

- H2 liquid target (SACM);
- Low-radius TPC;
- 3600 pads Micromegas endplate;
- AGET ASIC, FE & BE Electronics: evolution of T2K electronics;
- DAQ system .

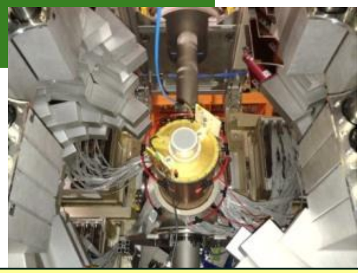




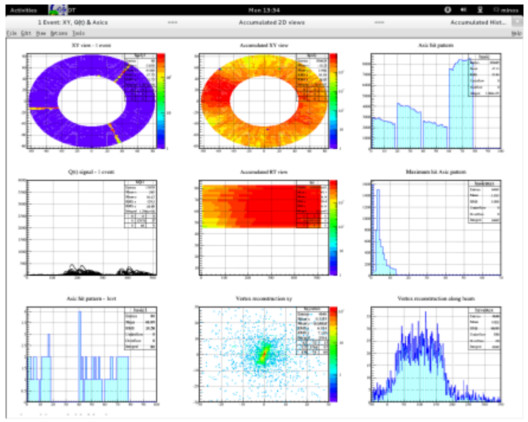
TPC End-Plate & field cage element. Internal R= 4cm

Instrument operation 2014-

- 2 succesful experiment campaigns @Riken in 2014
- See A.M. Corsi's talk



Minos inside the DALI spectrometer @ Riken



On-line screenshot of TPC events (SAMURAI 018)

Genetic multiplexing

from S. Procureur

Several possibilities to build the pattern, *i.e.* the sequence of p numbers:

→ *generate the sequence randomly:*

cannot build all the doublets

1_1	3_2	2_3	7_4	5_5	6_6	4_7
7_8	~~2~~ 1_9	5_{10}	~~6~~ 3_{11}	4_{12}	$\dots_{13}$	

channel # strip #

→ *build the i^{th} block from 1+k.i [n] (idea from Raphaël Dupré)*

build all the doublets if n prime

1_1	2_2	3_3	4_4	5_5	6_6	7_7
1_8	3_9	5_{10}	7_{11}	2_{12}	4_{13}	6_{14}
1_{15}	4_{16}	7_{17}	3_{18}	6_{19}	2_{20}	5_{21}

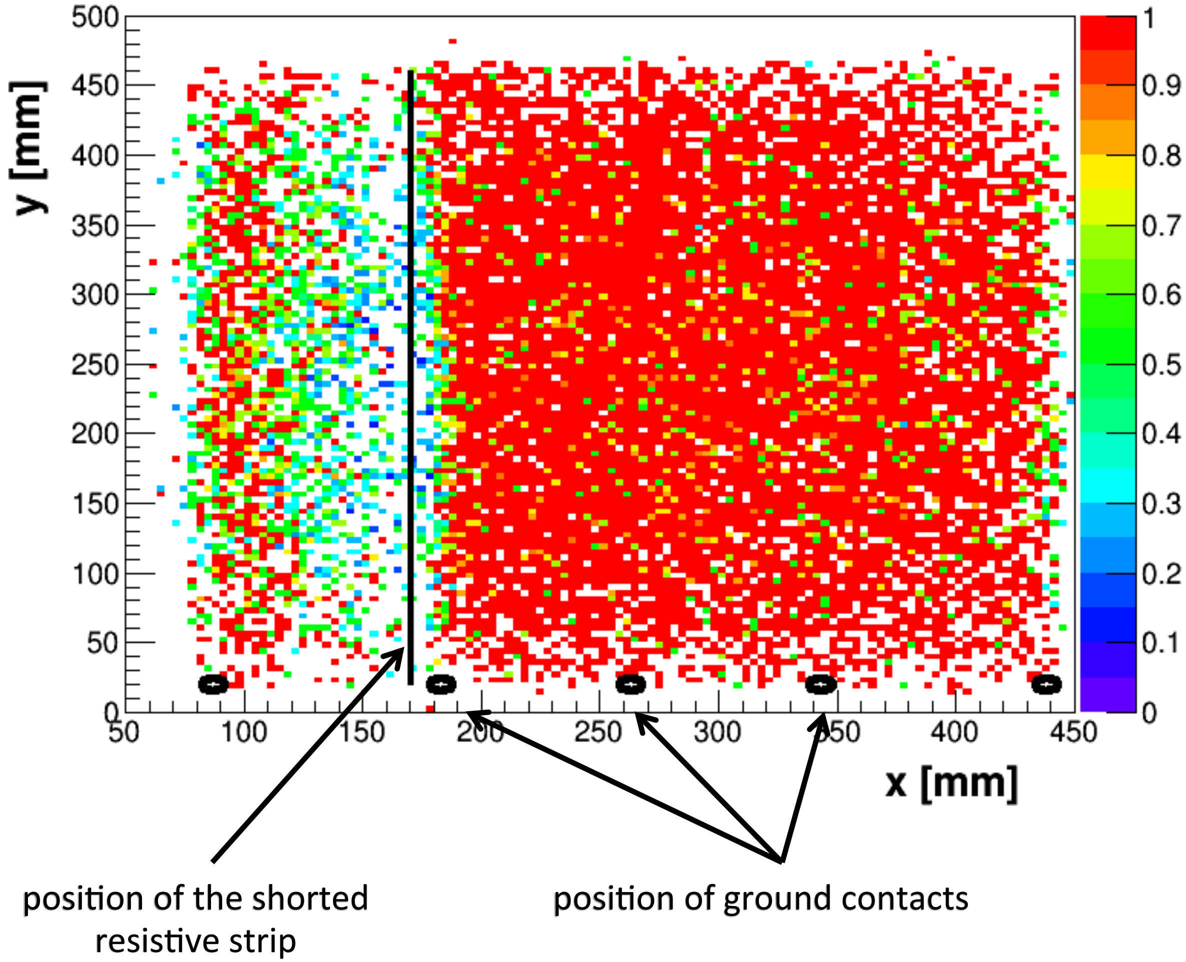
→ *idem, but simply use the first available channel*

build almost all the doublets ∀ n

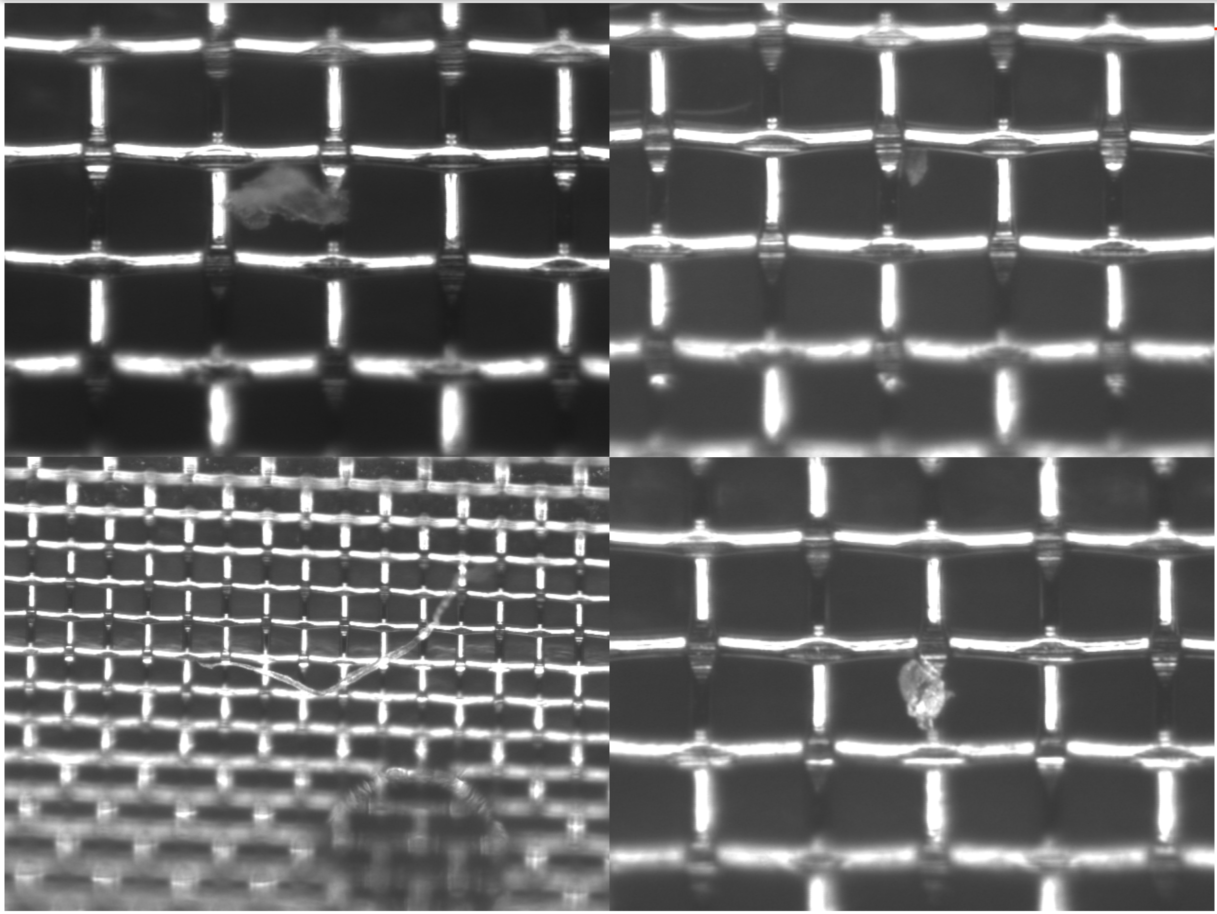
1_1	2_2	3_3	4_4	5_5	6_6	7_7	8_8	9_9
1_{10}	3_{11}	5_{12}	7_{13}	9_{14}	2_{15}	4_{16}	6_{17}	8_{18}
1_{19}	4_{20}	7_{21}	2_{22}	5_{23}	8_{24}	3_{25}	6_{26}	9_{27}
2_{28}	6_{29}	1_{30}	5_{31}	9_{32}	3_{33}	7_{34}		

Barrel prototype test with cosmic rays (2)

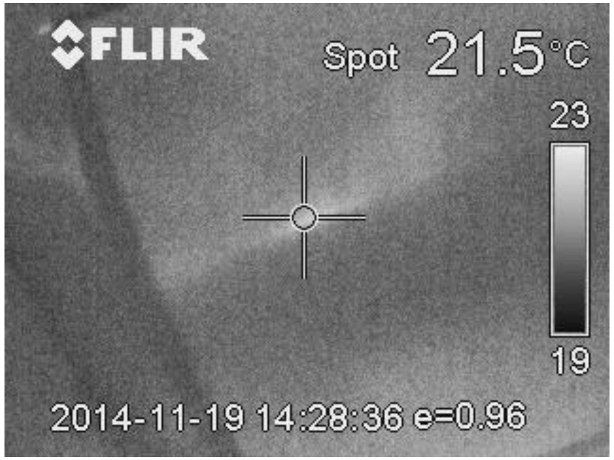
-> Then a few days later, a short appears between the micromesh and a resistive strip
-> The short induced a large current on a resistive strip
-> This current propagates via the ladders toward the ground of the resistive strips creating this inefficiency pattern:



Investigation of the cause of the short



Some defects observed with the Mitutoyo along a noisy strip.



Zoom on a part of the CLAS12 Barrel pre-series #2 with thermal cam, with HV on and current of about 300 μA

The defect has not been identified
Observation of the current with infra-red camera made

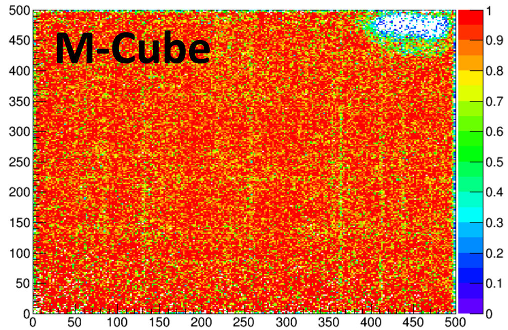
List of detectors tested

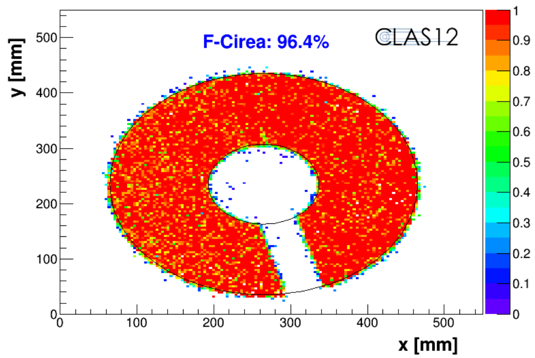
10 CLAS12 & M-Cube detectors were tested in our cosmic bench

⟶ 9 resistive + 1 non resistive

Detector	experiment	resistive	Active area	manufacturer	year	Drift frame
Forward prototype	CLAS12	Hand, no ladder	R=20 cm	ELVIA	2013	Epoxy
Forward preserie	CLAS12	Screen printing, ladders every 2 cm	R=18.5 cm	CERN	2014	?
Barrel preserie (x2)	CLAS12	Screen printing, ladders every 8 cm	45x37 cm²	CERN	2014	Carbon ribs
Forward Tagger prototype	CLAS12	no	R=14.6 cm	CERN	2013	Epoxy
MultiGen 2D (4x)	M-Cube	Screen printing with ladders	50x50 cm²	CERN	2014	Aluminum
MultiGen 2D	M-Cube	Screen printing with ladders	50x50 cm²	CERN+ELVIA	2014	Aluminum

⟶ Detectors without current between resistive strips and mesh are perfectly fine…





talk by S. Bouteille