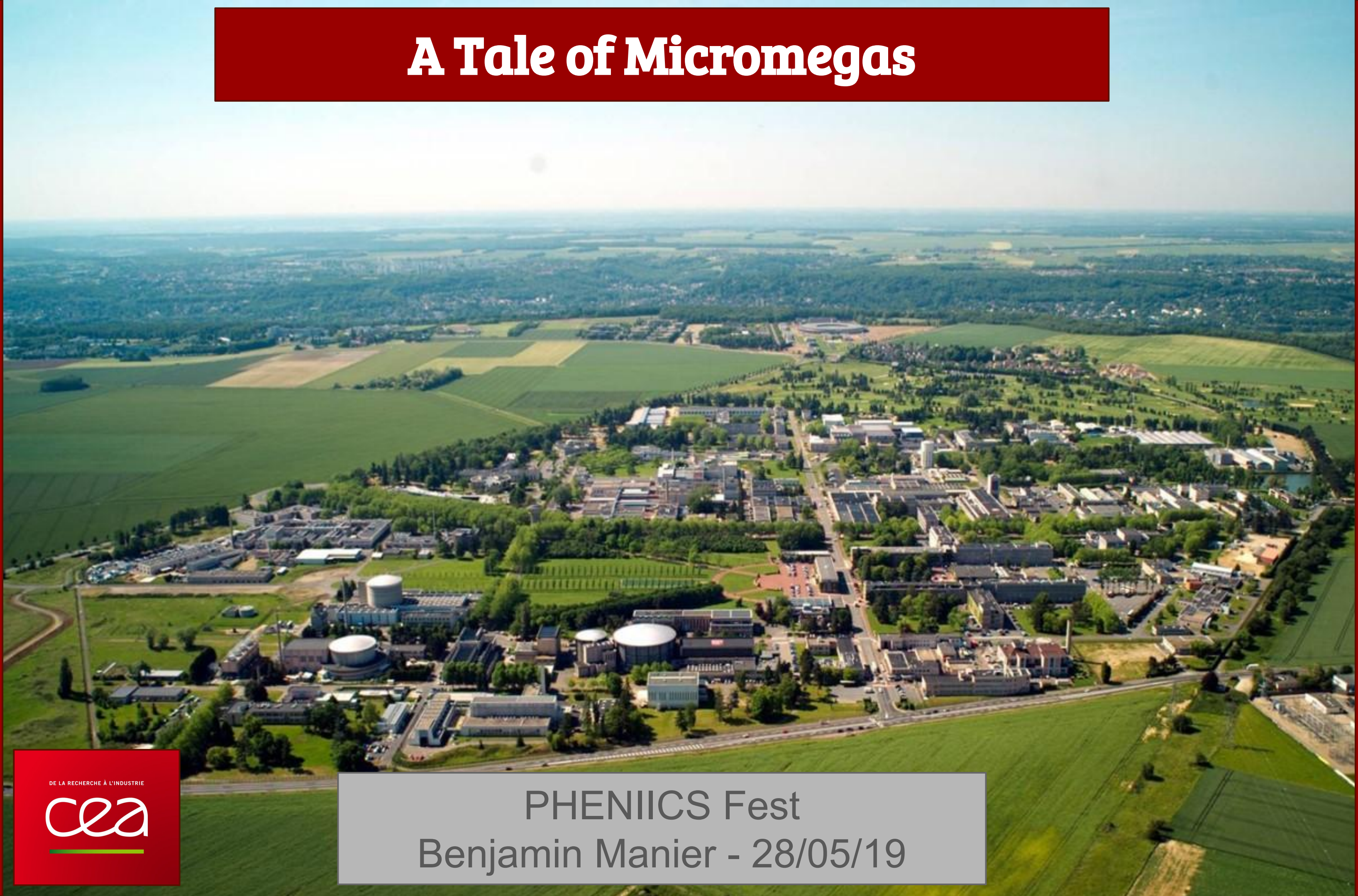
A Tale of Micromegas



PHENIICS Fest

Benjamin Manier - 28/05/19

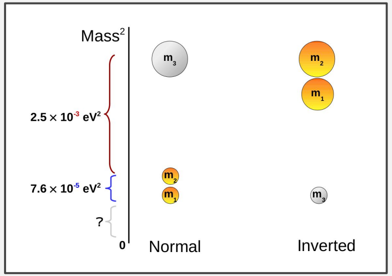
Summary

- Studying the neutrinos
  - Neutrinoless Double Beta decay
  - The PandaX-III Experiment
  - The need for MPGD
- MicroBulk Micromegas
  - Physics
  - Experimental Setup
  - Analysis
- Quality Control
  - Detector standard response
  - Physicals damages
  - Holes Quality

PandaX-III : a song of neutrinos and antineutrinos

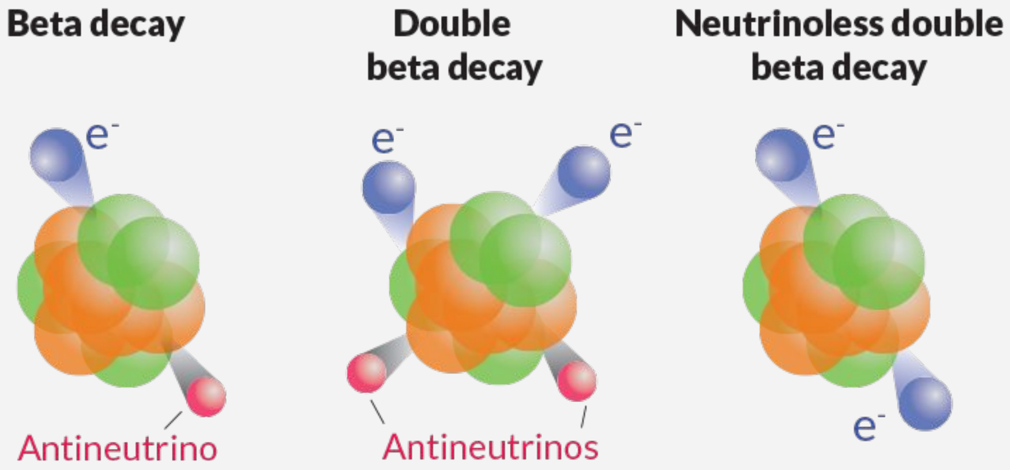
Neutrinos

- **Mostly unknown particles**
- Interact through the weak interaction and gravitation
- What is known :
  - It exists 3 flavours of neutrinos : Tau, Electronic and Muonic
  - 3 mass states exists
  - Neutrinos oscillate between the 3 flavours in their lives.
- Open questions ?
  - The absolute and relative masses of the neutrinos ?
  - Are they majorana particles ?
  - The oscillation matrix between the flavours ?
  - ...
- In our case : **is the neutrino its own antiparticle (Majorana Neutrinos) or not (Dirac Neutrinos) ?**



Mass Hierarchy between the three known neutrinos

Studying the neutrinos

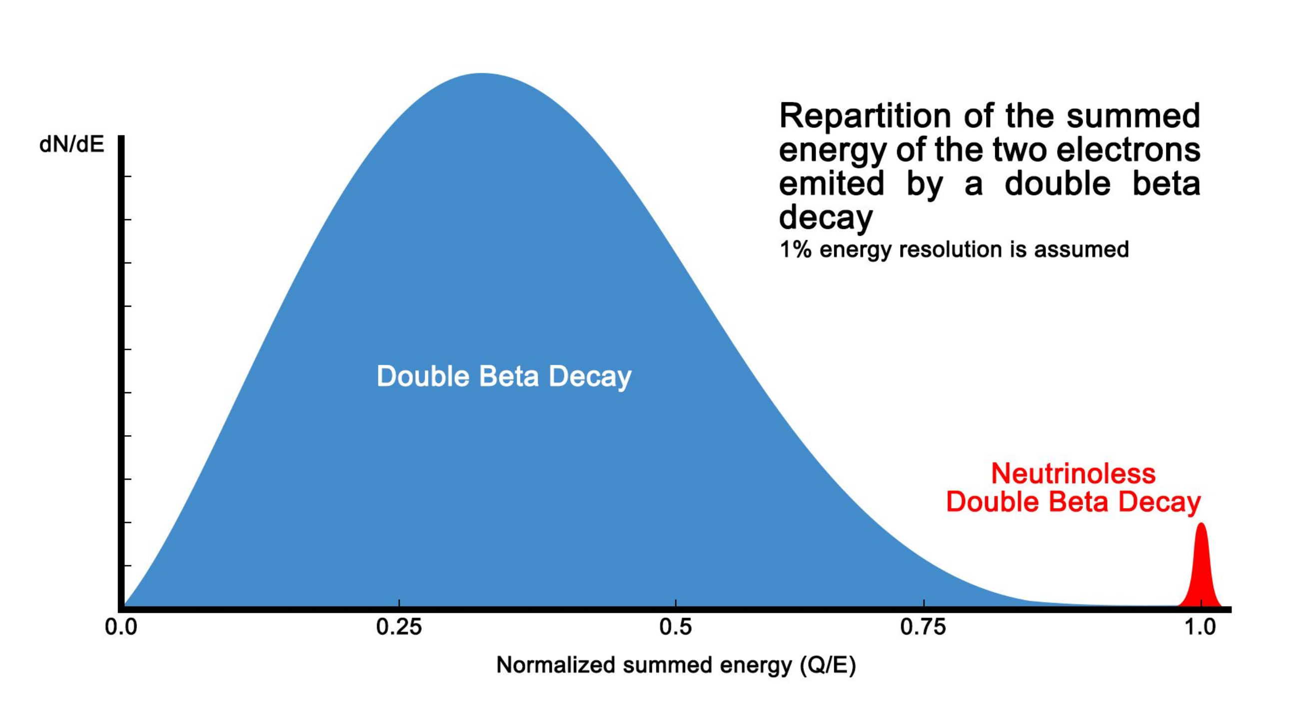


Known elements to decay through double beta decay (Half-life ≈10^{21} years)

- ^{48}Ca
- ^{76}Ge
- ^{78}Kr
- ^{82}Se
- ^{96}Zr
- ^{100}Mo
- ^{116}Cd
- ^{128}Te
- ^{130}Te
- ^{124}Xe
- **^{136}Xe**
- ^{130}Ba
- ^{150}Nd
- ^{238}U

In the case neutrinos are majorana particles, **we can observe neutrinoless double beta decay (NDBD) in a select few elements.**

Studying the neutrinos

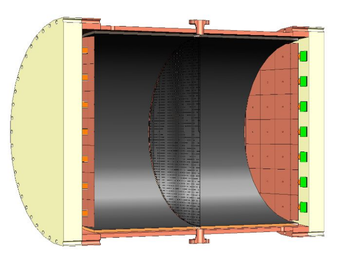


Provided that we can measure the energy of the two emitted electron we can separate with the energy double beta decays from neutrinoless double beta decay.

PandaX-III

- A rare events search experiment : that study **Neutrinoless Double Beta Decay** through the disintegration of Xenon 136
- Laboratory :
  - Located in China
  - Jinping Underground Laboratory
- The experiment
  - **Ton scale experiment** (5 modules - 200kg)
  - Detection of the diffused electron coming from the double beta decays
  - **Detection with XY micromegas**
- Requirement
  - **Sufficient energy resolution required** (<1% at 2.5 MeV)
  - Ultra low background (**radiopure detectors**)
  - Very good event reconstruction **to discriminate background events**

China Jinping Underground Laboratory

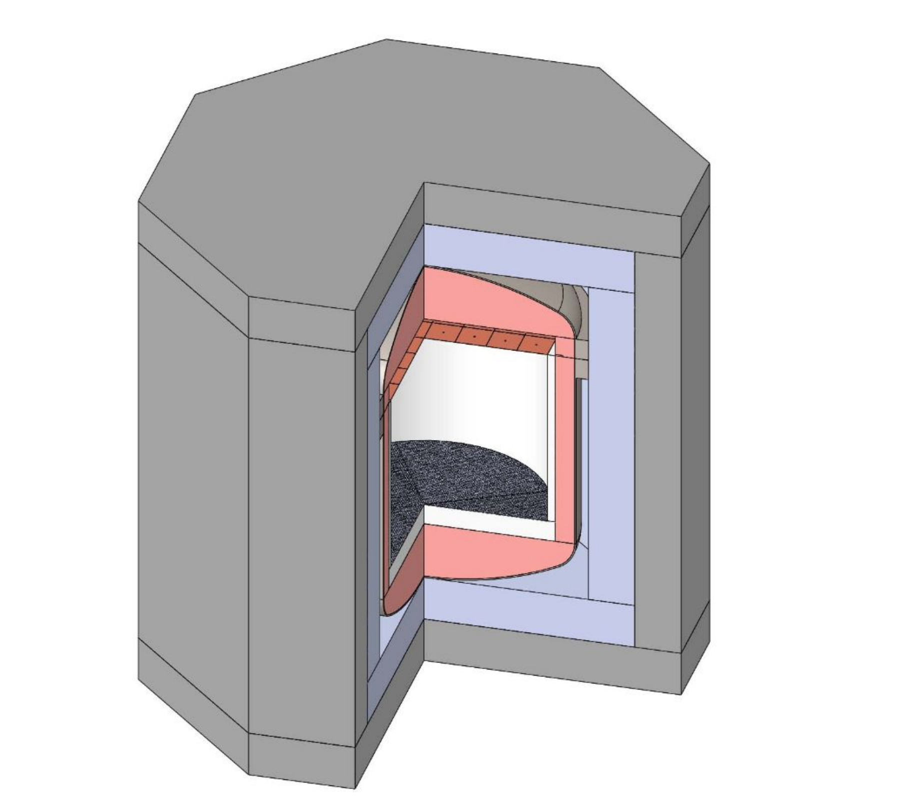


One module of PandaX-III filled with 200kg of ^{136}Xe.

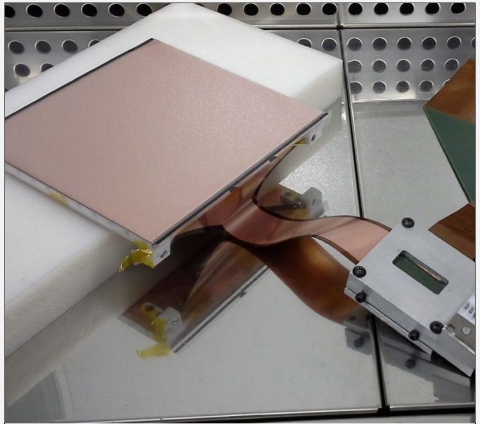
DE LA RECHERCHE À L'INDUSTRIE

cea

One PandaX-III Module



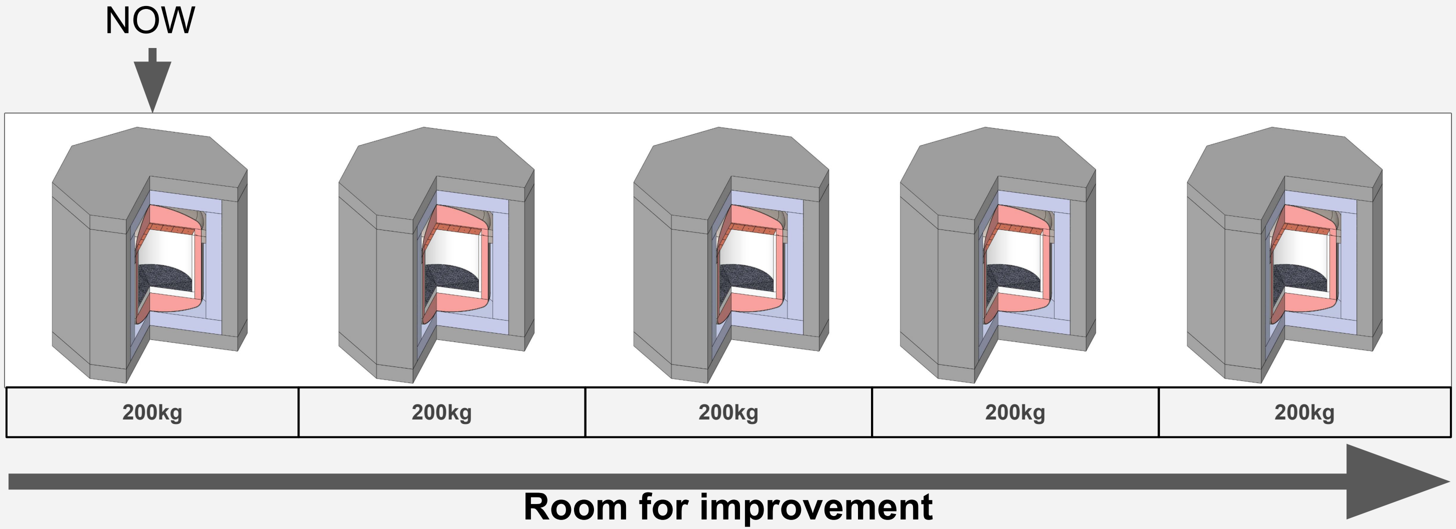
A single module (200 kg of ^{136}Xe) with all the shielding



One micromegas of the detector array

- From outer to inner layer :
  - Lead
  - Polyethylene
  - Inox Vessel
  - Copper
  - PTFE-Teflon
  - 10 bar ^{136}Xe

Five PandaX-III Modules



The modularity of the 5 future modules allows to **conduct extensive R&D activities** during the operation of the build TPC while maintaining its ability to scale to a 1T experiment.

GEMS

FAKIR

MICRO ORWELL

MICROMEGAS BULK

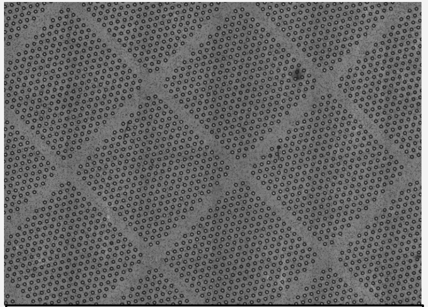
MICROMEGAS MICROBULK

RESISTIVE MICROMEGAS

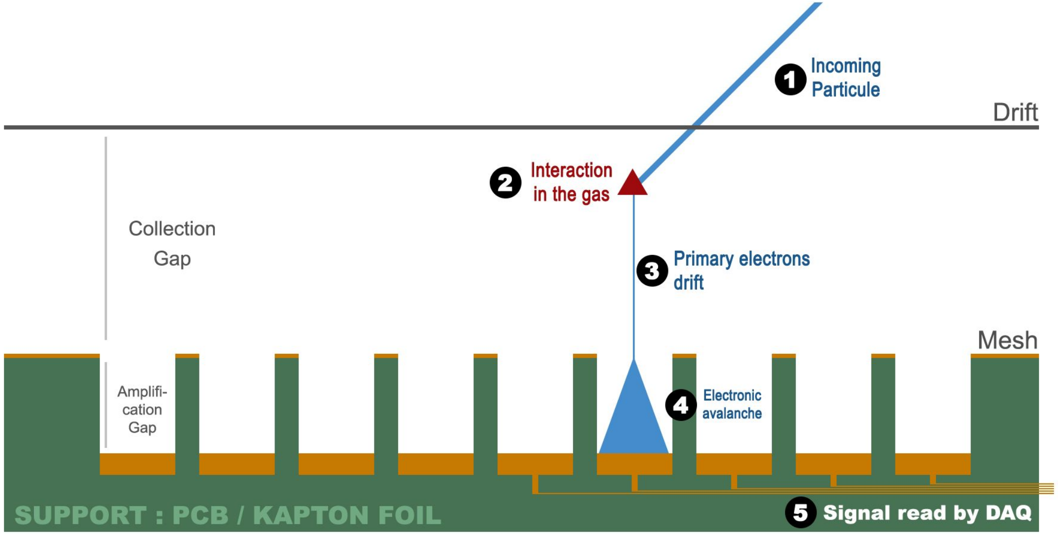
50 Shades of Micro Gaseous Pattern Detectors

WIRE CHAMBER

Microbulk Micromegas in action



Diamond-shaped pads of the detector composed of several holes



Schematic of a Microbulk Micromegas

Collection Gap :

A light electric field drives the collected electrons to the mesh

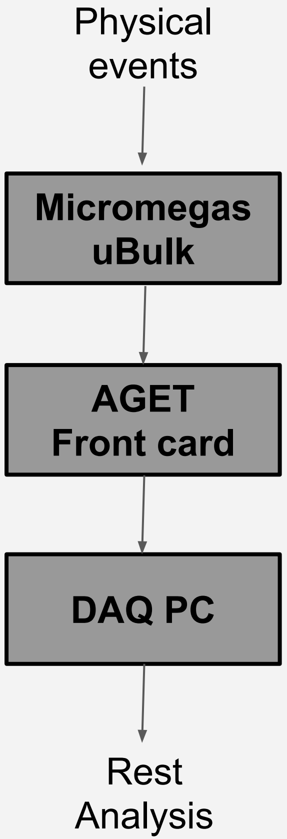
Amplification Gap :

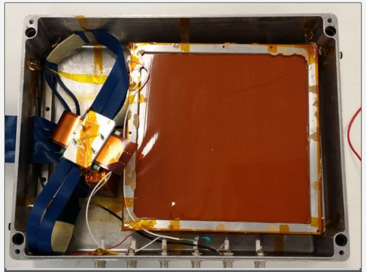
A stronger field located inside the holes that allows the creation of an electronic avalanche that amplify the collected electrons to a readable signal.

Experimental Set-up

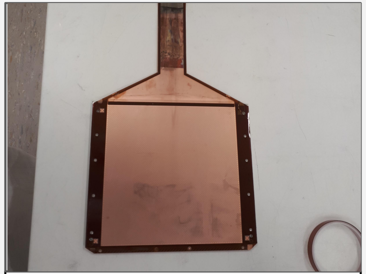
- Detector :
  - XY microbulk micromegas
  - 50 um amplification gap
  - 1 cm drift gap

- Setup parameters :
  - Gas : Argon - Isobutane 5%
  - Tensions :
    - Drift : 800 V
    - Mesh : 300-350 V
    - VStrips : grounded



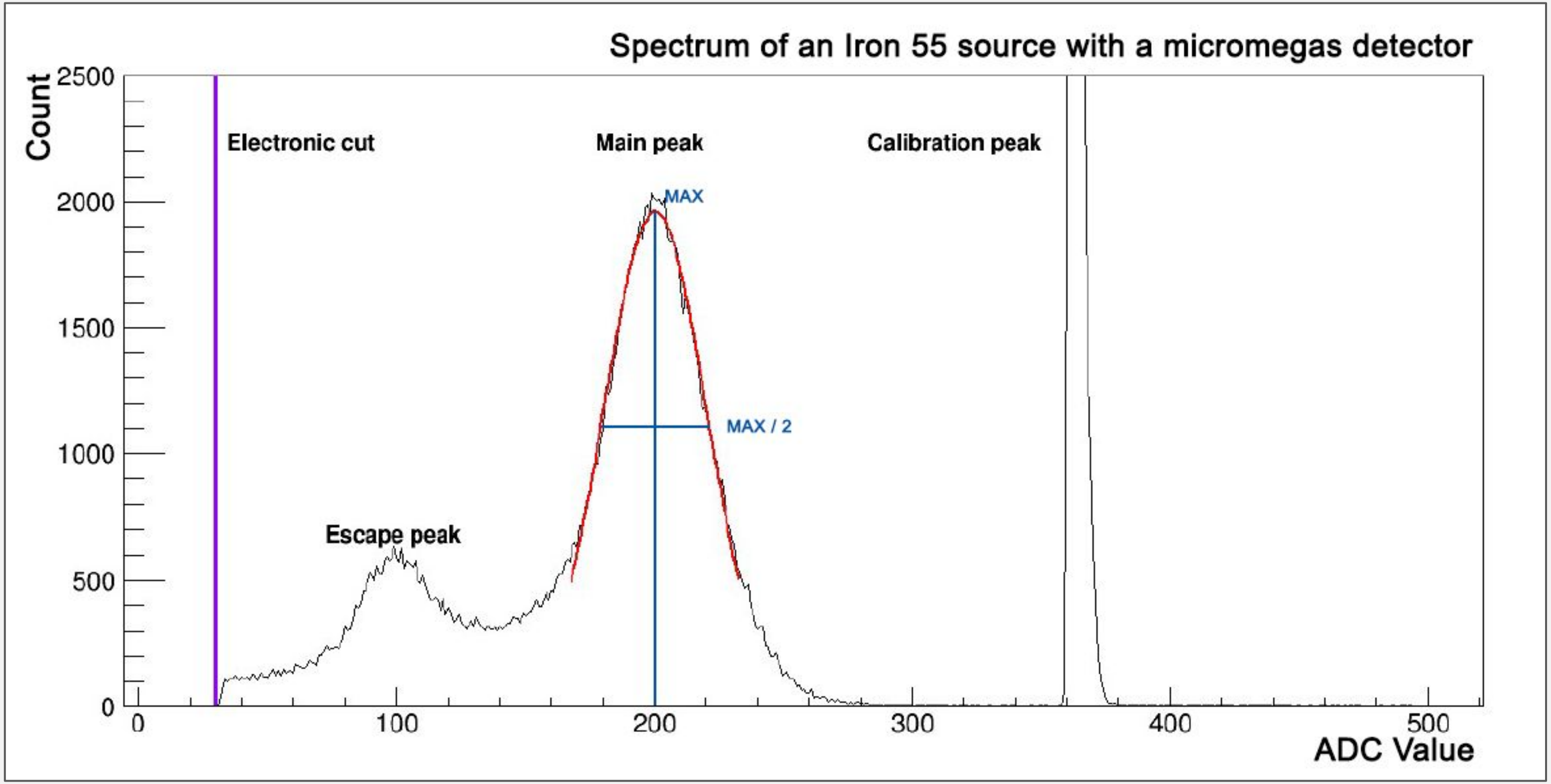


The PandaX-III Microbulk in his setup



The PandaX-III detector, itself !

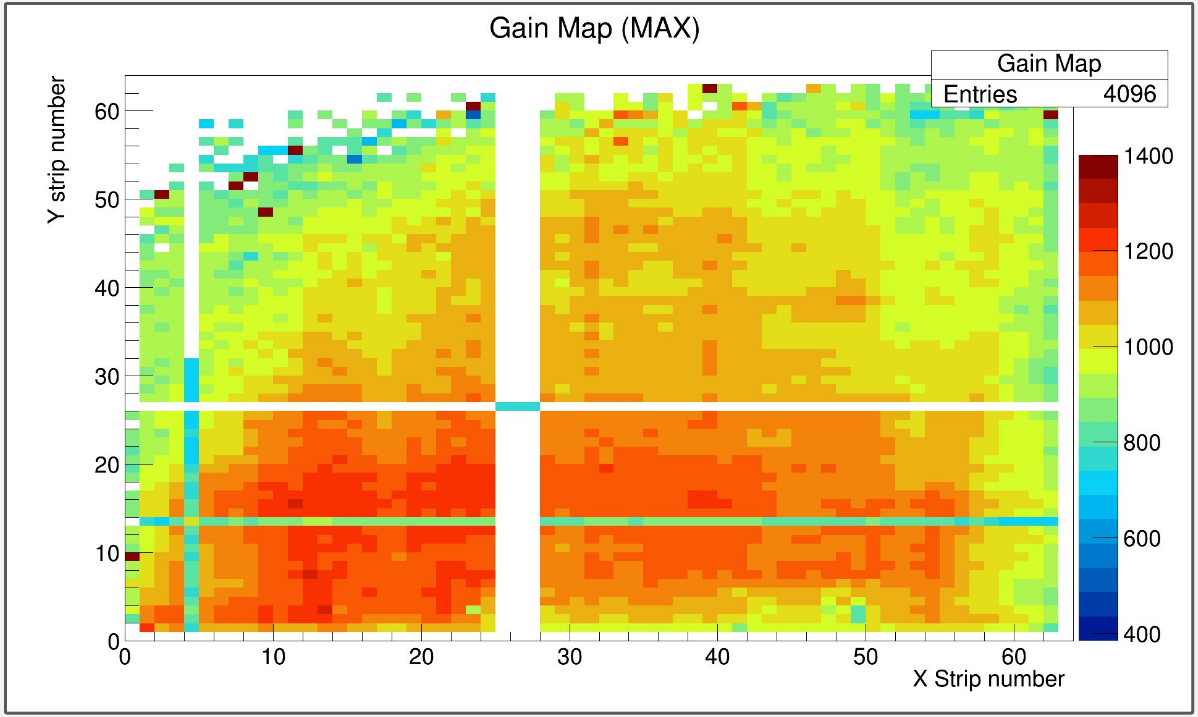
Experimental Set-up



GAIN :
Calculated with relative positions of the Calibration peak and the Main peak.

RESOLUTION (FWHM):
The Full Width Half Maximum Resolution is calculated by measuring the width of the main peak at its half maximum.

Global gain homogeneity



All events :
above threshold
XY events (at least 1 X strip and 1 Y strip fired)

Argon-Isobutane 5%

^{55}Fe source

Vmesh = 350 V
Vdrift = 800V

We observe variation going from 800 to 1400 on this detector at a given gain.

Microbulk : Quality Checks

Introduction

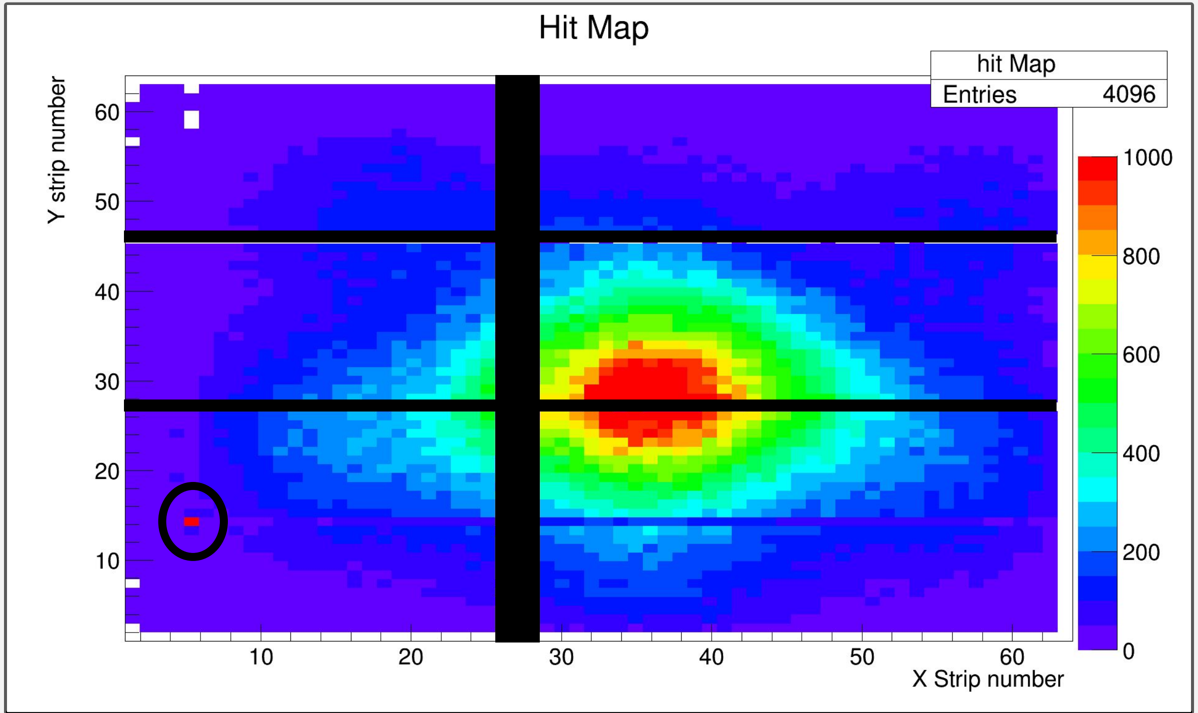
I. Neutrinos
- A. Double Beta Decay
- B. PandaX-III
- C. MPGD

II. Microbulk Micromegas
- A. Physics
- B. Setup
- C. Analysis

III. Quality Control
- **A. Standard Response**
- B. Damages
- C. Holes Quality

Conclusion

Defects on a micromegas



Hit map of a Fe55 source run in Argon isobutane 5%. The Fe55 source is located roughly at pixel (37;30). We can see the five cut channels, and the coupled pixels.

The detector has 5 cut channels due to sparking (black parts). The cut strips are left floating in the detector.

It also has 2 coupled strips (black circle).

How to detected it ?

By measuring the capacitances of each strips.

$C_{Cut\ Strips} = 0$ F
$C_{connected} = n * C_{Normal\ strip}$
With n the number of connected strips.

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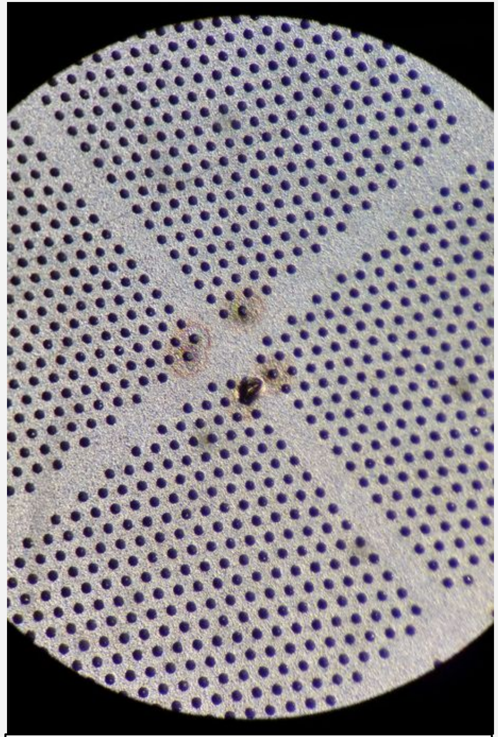
Detector damages



A notch between two pads that create sparks.

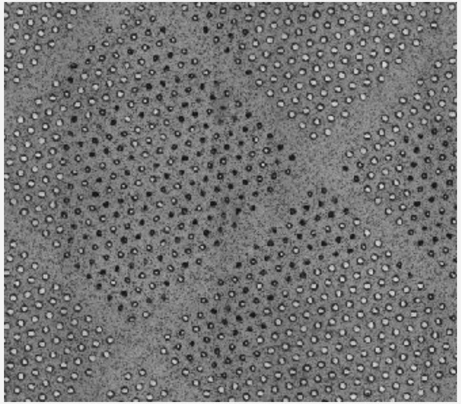
The damages done by a spark.

Damages
- Connection between the Mesh and one strip
- Connection between two strips
- Cut in the detector tail

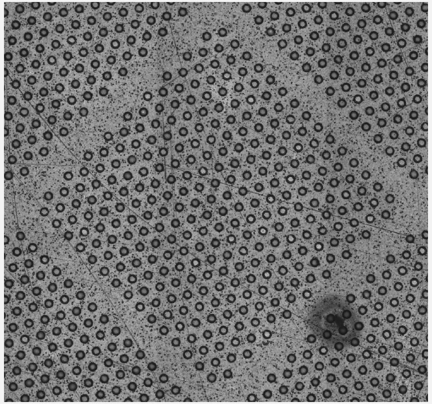
Solution :
- Careful handling
- Better base design
- Manufacturing procedures

Control :
- **Measure the quality of the holes with a microscope**
- **Measure the capacity of the strips**

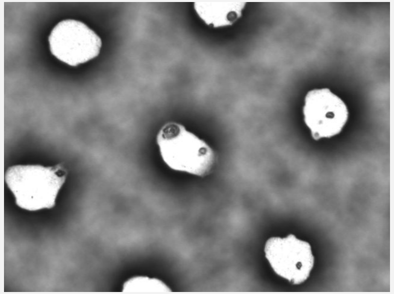
Hole Quality



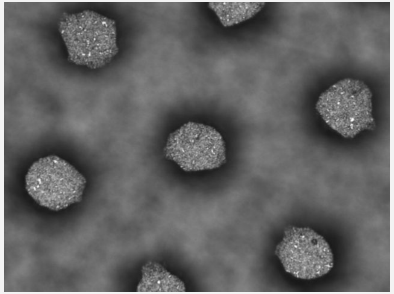
Closed Holes (black dot) alongside open holes (white holes)



Semi-closed holes



Chromium at the bottom of the holes



Copper at the bottom of the holes

Different qualities of holes are present : **Closed holes** (Black dots on the left image), **semi-closed** holes with a dark circle (right image), and **normal holes** (every white holes).

Three defects are identified :

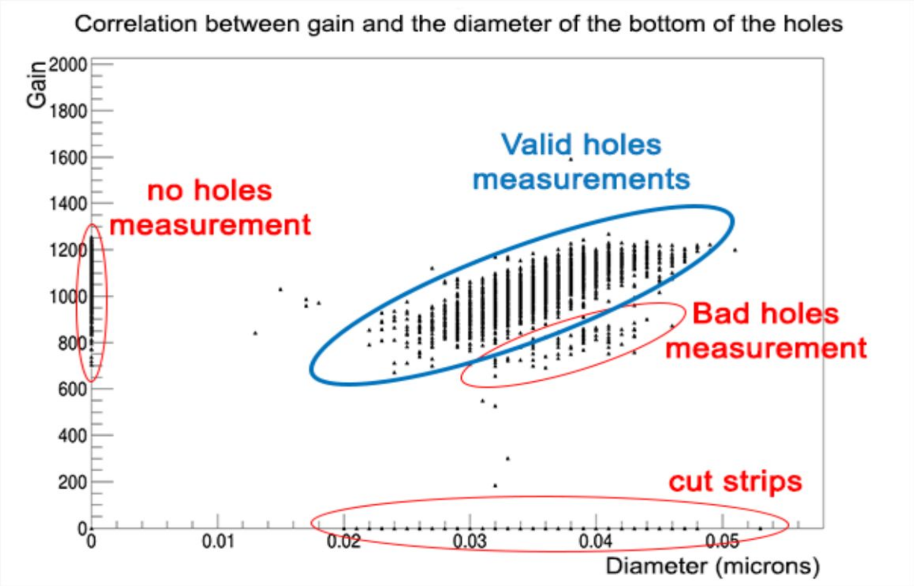
- Non circular holes
- Closed holes

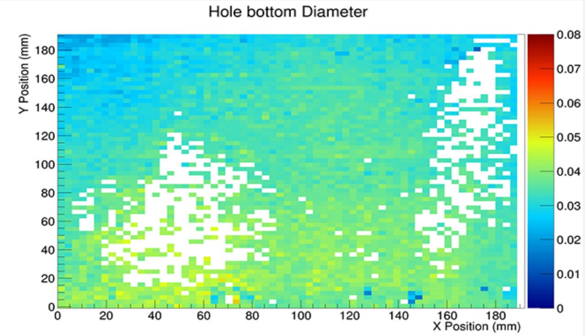
| Holes drilling problem

- Chromium staying at the bottom of some holes | Holes polish problem

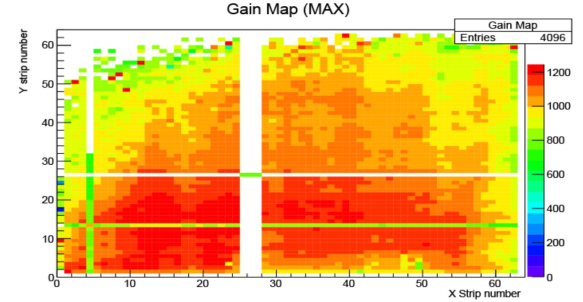
| **Need for quality checks**

Gain and hole quality





Holes Bottom Diameter



Gain Map of a Microbulk Micromegas

The bottom diameter of the holes correlates well with the gain of each pixels.

Therefore, even small defects not only create shortcuts between the strips and the mesh but also affect the gain of each pixel.

Hole Quality impact on performances

Closed Hole	Semi Closed Hole	Normal Hole
No Gain	Degraded Gain	Normal Gain

Examining the hole quality is mandatory to have a good understanding of the overall comportment of any microbulk Micromegas

Conclusion

- In Situ quality checks should be present for mass production :
  - Connections tests
  - Capacity measurements

- Further Quality checks needed for each detector :
  - Hole quality check

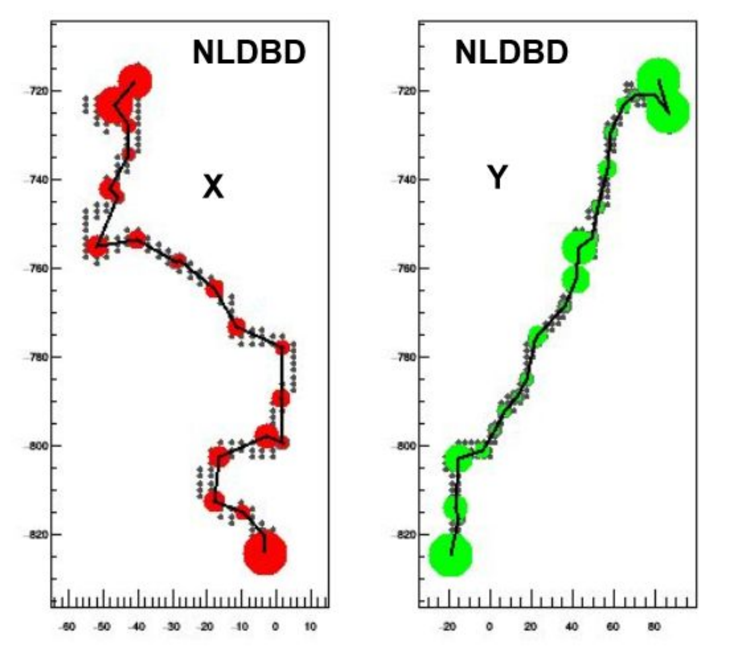
- Need to explore the ways to mitigate damages :
  - Extrapolate cut strip/pixel from neighbouring signal
  - Non destructive handling of connections between the mesh and the strips.


Thank you for listening

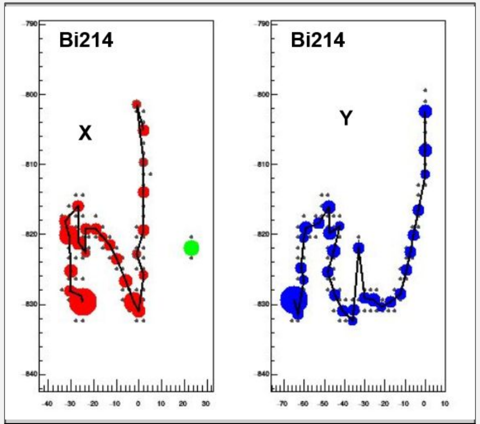
Backup

Analysis tools to handle noise.

- Goal : Discriminate Double beta event from remaining noise signal



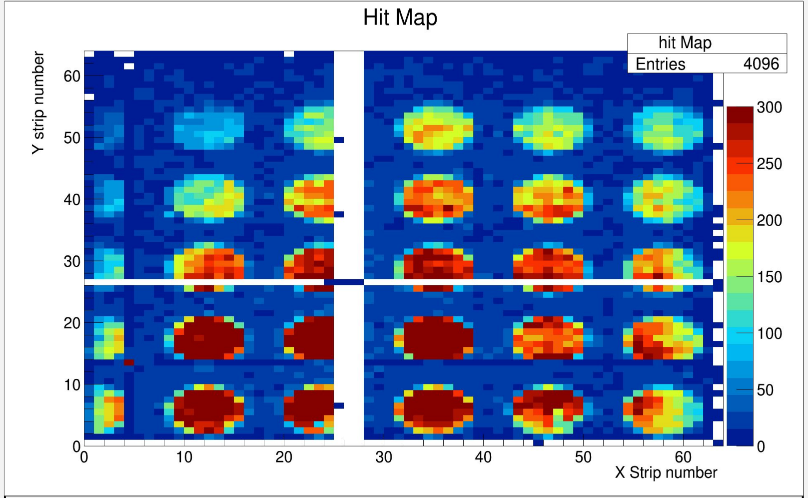
A typical Double Beta event, with two cluster of high deposited energy representing the location where the two emitted electrons were stopped in the Xenon gas.



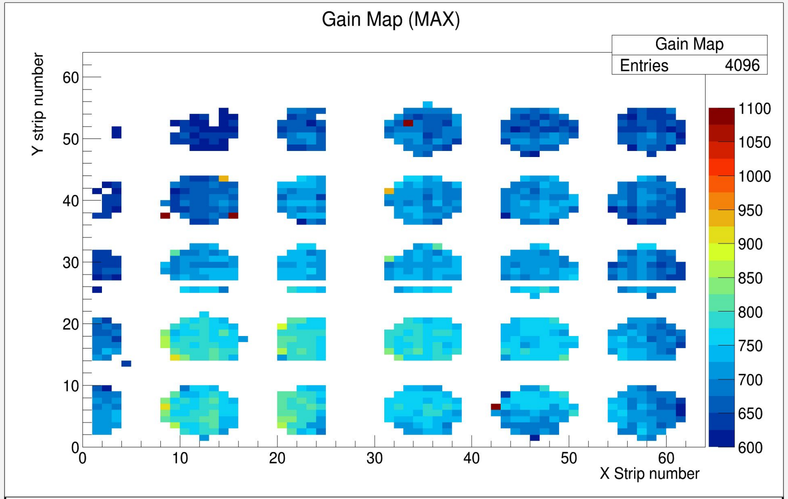
A noise event.

- **Analysis Software :**
  - REST
- **Method :**
  - Blob recognition
  - Energy repartition
  - Track recognition
  - Neural network

Experimental limits : the shield box



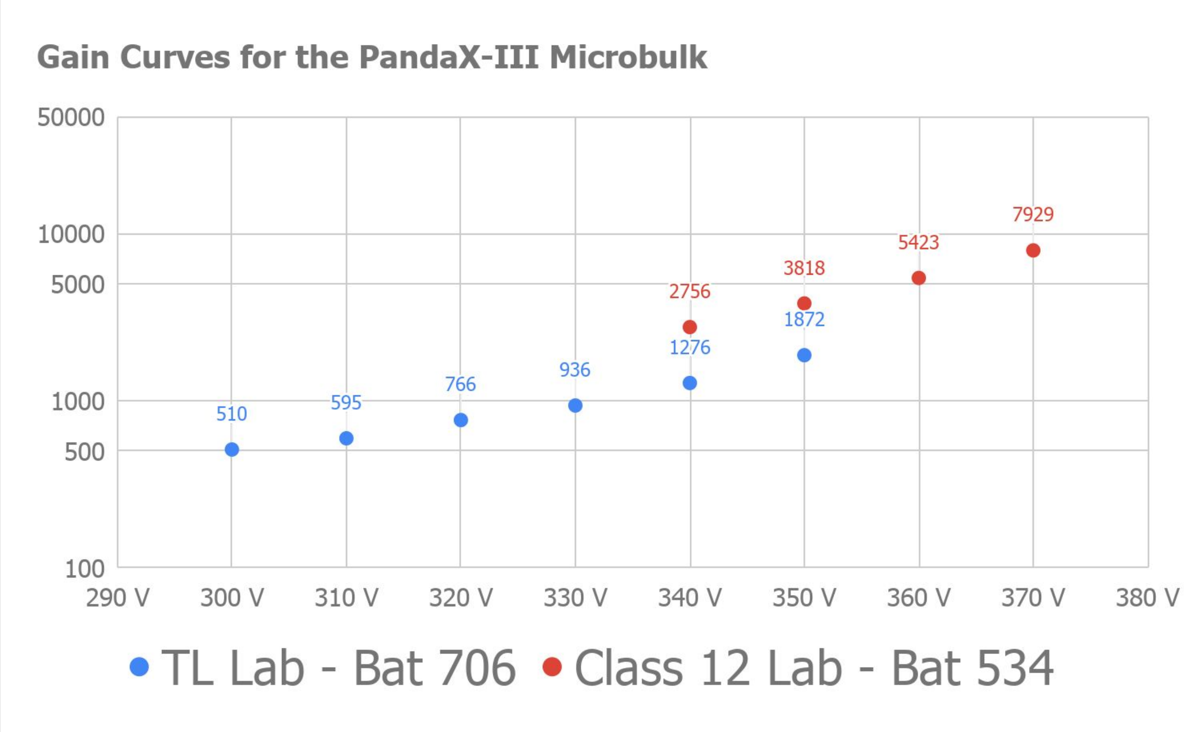
Hit Map with a Fe55 source at 50cm



Gain Map with a Fe55 source at 50cm

The windows don’t allow to light the whole detector in one run, hence the need for multiple runs to take the data.

Influence of gas quality



Gain curve of the full PandaX-III detector done with a Fe55 source.

All events above threshold

Argon-Isobutane 5%

^{55}Fe source

The gas is coming from two different bottles

The gas is coming from a premix bottle

A difficulty to get XY events

Issue :

To get a good estimate of the global reliability of the detector, we need to get a good measure for each of its pixel.

At V_{mesh} = 300 V		
Initial events	100	
After threshold	73	
Nature	Pure X	36.35
	Pure Y	36.35
	XY	0.3

At low gain, the signals that are selected by the threshold are those located majoritarily on one strip, the complementary axe doesn't go above the threshold. Resulting in a very low number of XY events, and a higher proportion of noise events (electromagnetic pickup)

At V_{mesh} = 350 V		
Initial events	100	
After threshold	97	
Nature	Pure X	30.5
	Pure Y	30.5
	XY	36

At high gain, the signals mostly are above the threshold, we have still 60 % of the events that are single strip event. Meaning that either we have a pixel size large compared to the diffusion size of the event, or a high noise that masks the XY information.

Pure X event :
The event hits only one X strip.

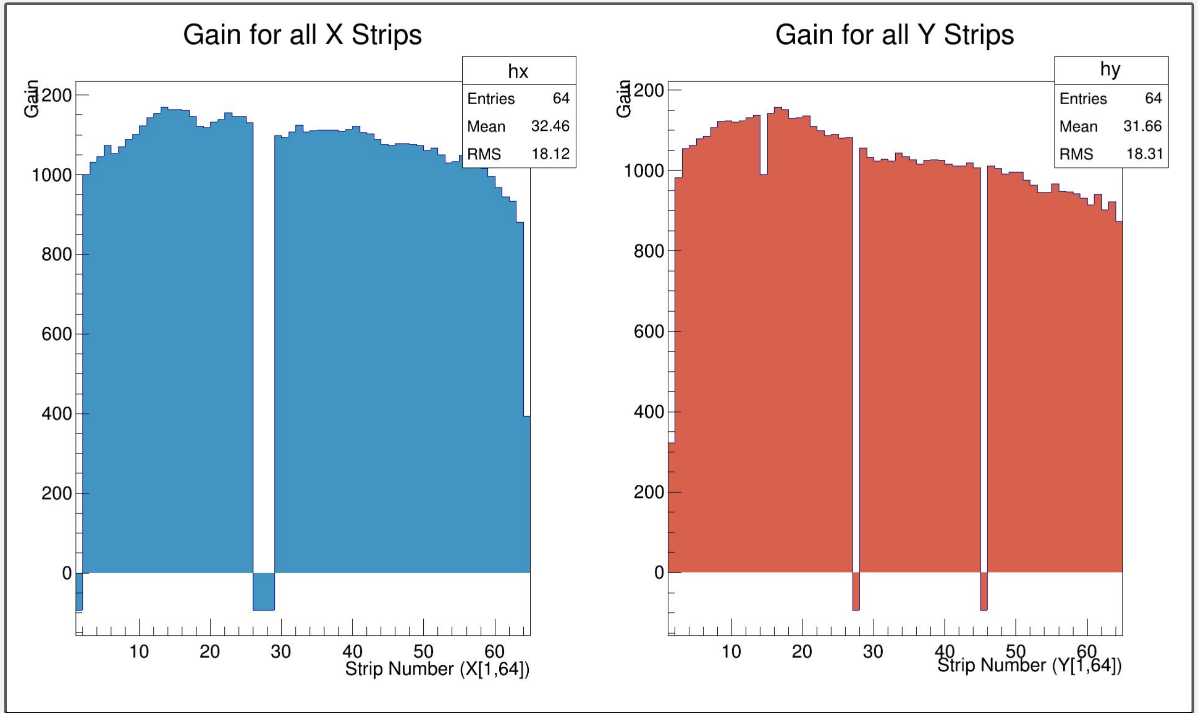
Pure Y Event :
The event hit only one Y strip.

Pure XY Event :
The event hit at least one X strip and at least one Y strip. The strips with the maximum values are taken to get the event position on the detector.

Solution:

Operate at high gain and select carefully the kind of event (Pure X, Pure Y, XY events)

Strip by strip gain



Gain Map for each strips of the full PandaX-III detector done with a Fe55 source. The source was displaced across the detector to provide a full enlightenment of the detector. Negative gain values account for a too low statistics to fit correctly the strip.

All events :
above threshold
are on one strip (Pure X / Pure Y)

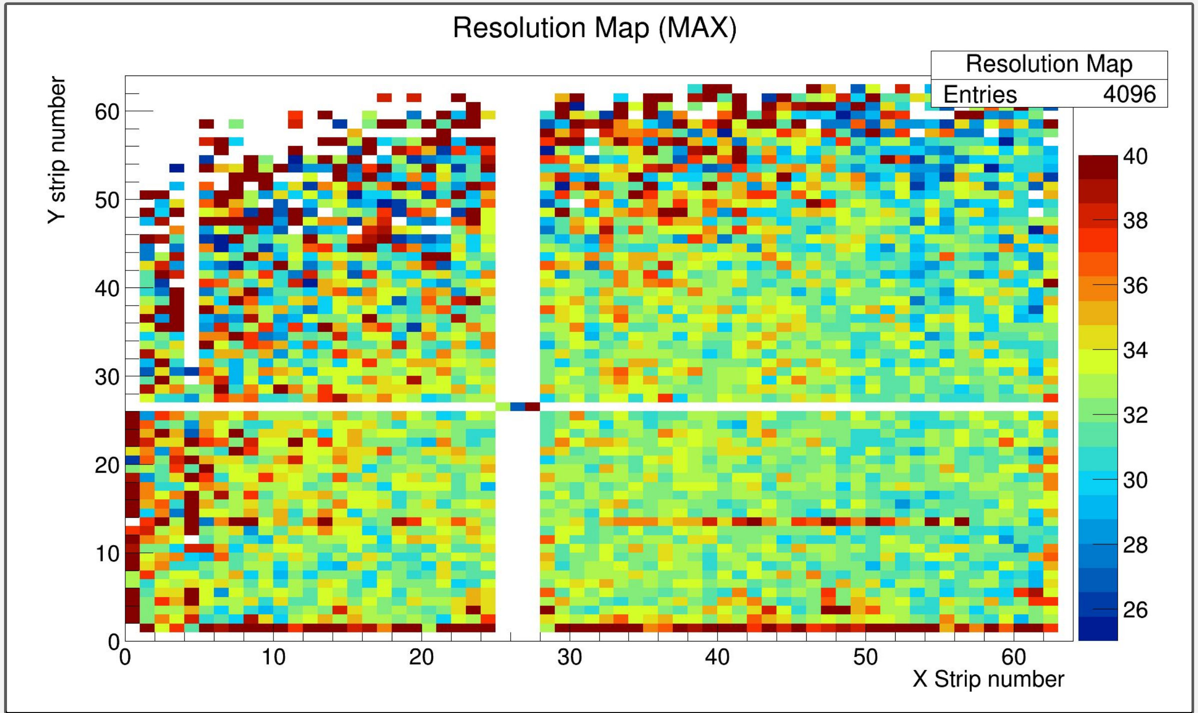
Argon-Isobutane 5%

^{55}Fe source

Vmesh = 350 V
Vdrift = 800V

TL Laboratory
Bat 706
The gaz is coming from a premix bottle

Global energy resolution homogeneity



Energy resolution map of the full PandaX-III detector done with a Fe55 source. The source was displaced across the detector to provide a full enlightenment of the detector.

All events :

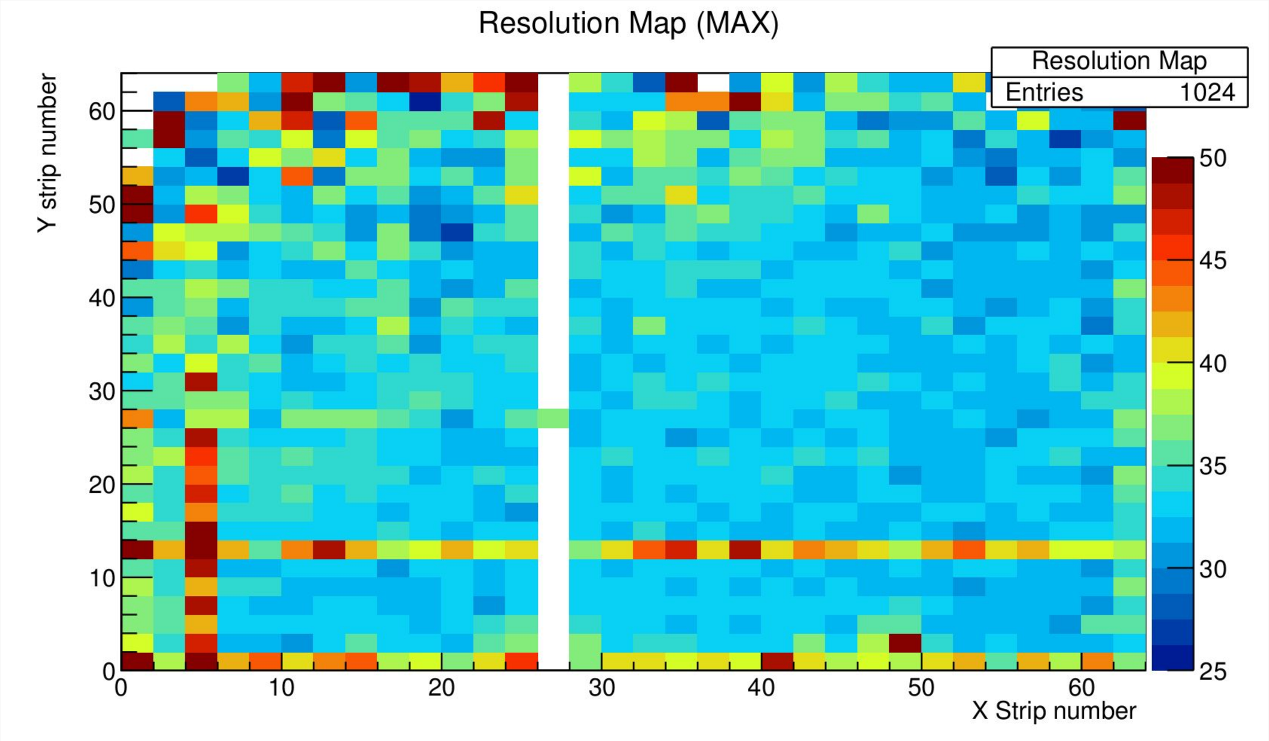
above threshold

XY events (at least 1 X strip and 1 Y strip fired)

Argon-Isobutane 5%

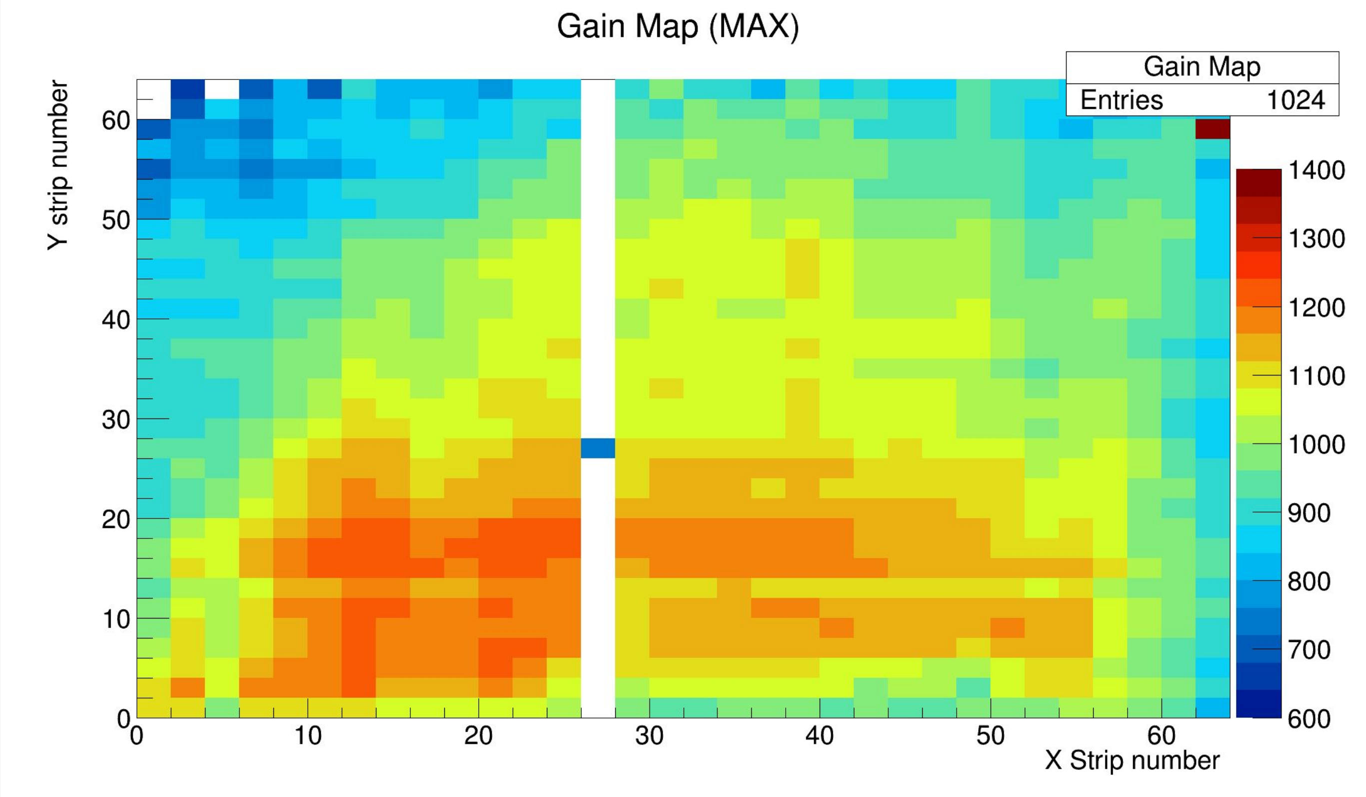
^{55}Fe source

2x2



Resolution Map (MAX)
Resolution Map
Entries 1024
Y strip number
X Strip number
0
10
20
30
40
50
60
25
30
35
40
45
50

2x2


Gain Map (MAX)
Gain Map
Entries 1024
Y strip number
X Strip number
0
10
20
30
40
50
60
1400
1300
1200
1100
1000
900
800
700
600