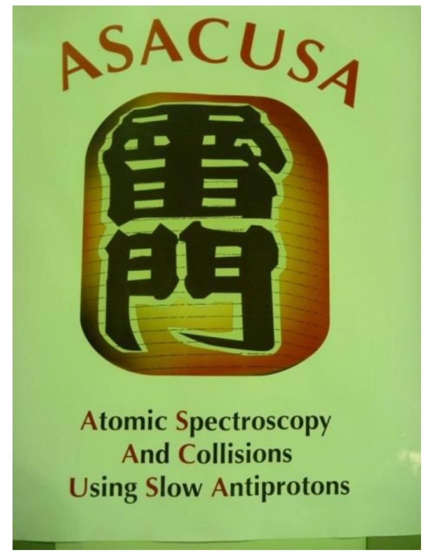
FROM RESEARCH TO INDUSTRY

# IRFU
# Scientific Council

## CEA Saclay

## 2015, January 14 &15 th




Philippe Legou IRFU - SEDI

CEA - Saclay

www.cea.fr

# SUMMARY

1. ASACUSA Experiment

2. ASACUSA Micromegas Tracker (AMT)

   ⇨ Prototype

   ⇨ Final design – test & characterisation at Saclay

3. Readout Electronics

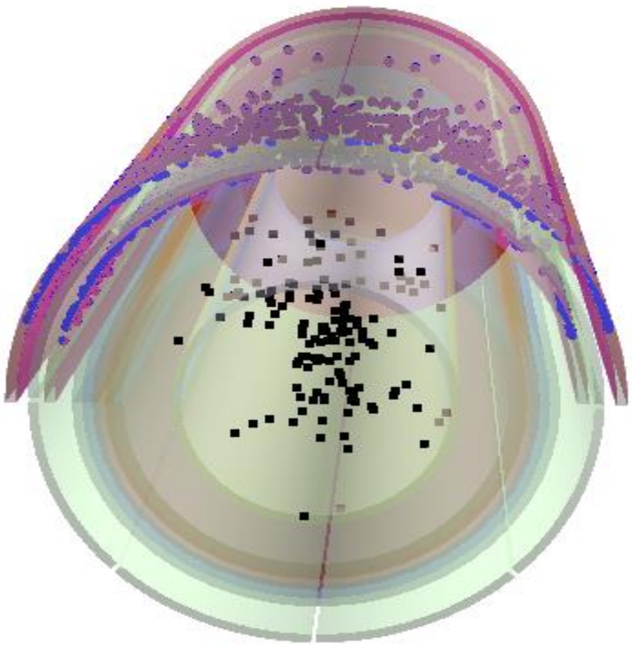
   ⇨ Overview

   ⇨ DREAM Electronics

4. AMT @ CERN

   ⇨ Installation

   ⇨ Results



# ASACUSA @ CERN

- Goal

  ASACUSA compares matter and antimatter by comparing the spectra of antihydrogen why those of hydrogen, one of the most precisely investigated and best understood systems in modern physics (ASACUSA is very famous in the domain of matter and antimatter).

- Where?

  AD Building – CERN

- How?

  In order to do that, a tracker detector is needed to reconstruct the annihilation position of the antihydrogen particles while they are being formed in a trap.
  From the knowledge of the antihydrogen annihilation position, we can understand and improve the antihydrogen beam.
  Since the know-how concerning curved Micromégas détector was present in IRFU thanks to CLASS 12 experiment, professor Yasunori Yamazaki the leader of this up-rising experiment asked to IRFU the developpement of this tracker using Micromégas technology.

# THE ASACUSA EXPERIMENT

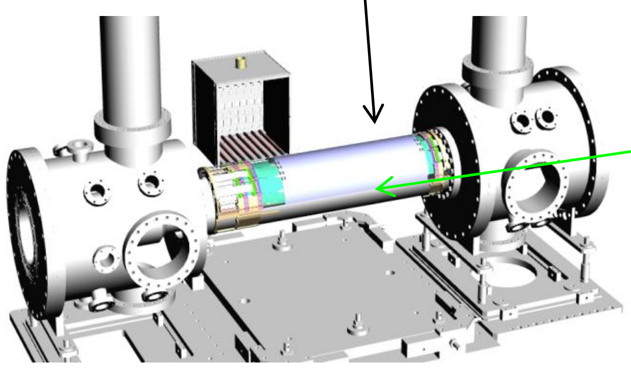
Positron and anti-proton in the “CUSP” trap where the anti-H is formed

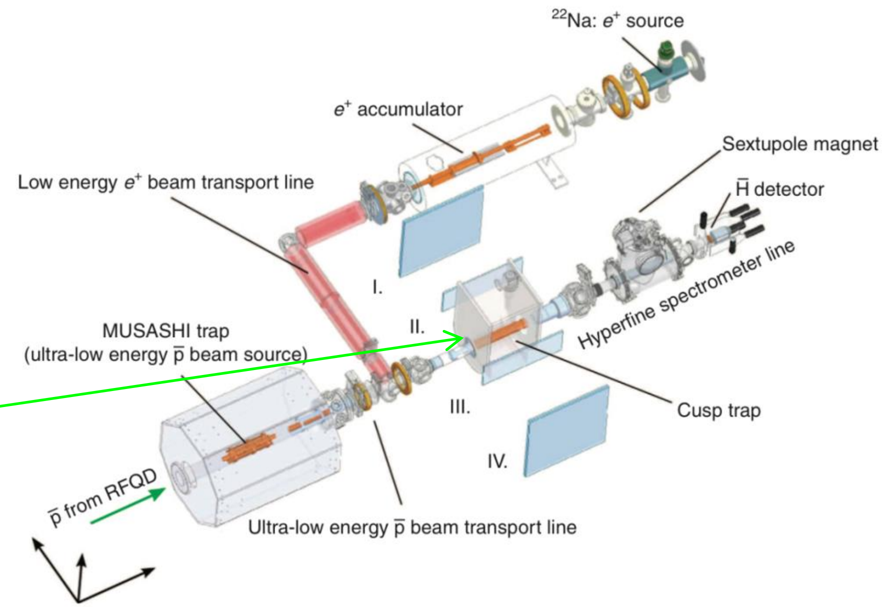
Target annihilation vertex resolution: < 1 cm to distinguish between rest gas and vacuum chamber  wall

The targeted spatial resolution for C and Z coordinates is 250 µm

Annihilation rate: ~10-50 kHz

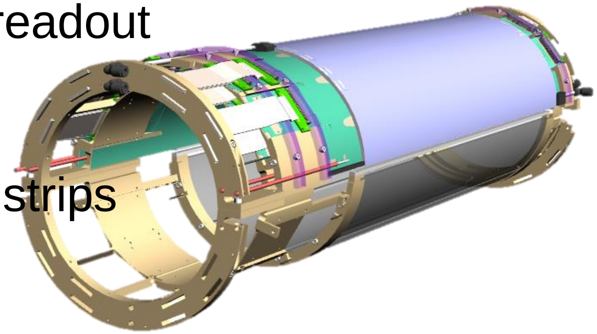
ASACUSA Micromegas Tracker-AMT



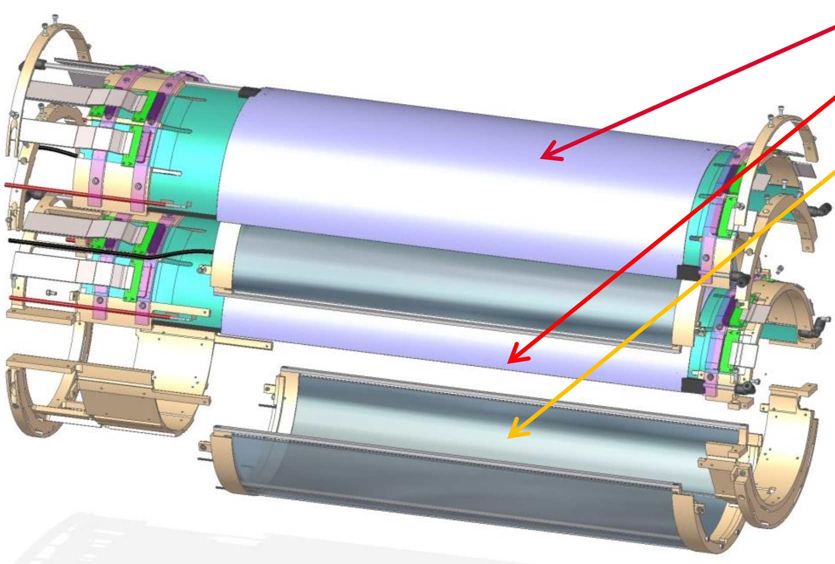


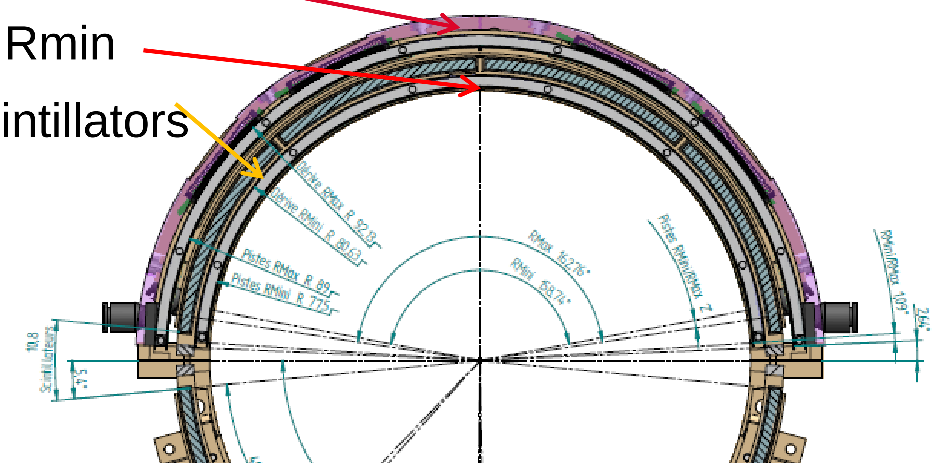
# THE ASACUSA MICROMEGAS TRACKER - AMT -

2 Cylindrical layers = 4 Micromegas Chambers with 2D readout
Chamber size: length 60 cm with 85 & 95 mm radii
3mm drift gap
0,87 mm pitch: 250 longitudinal Z strips, 500 circulars C strips
8 Curved trigger scintillator bars



## High magnetic field up to 4T

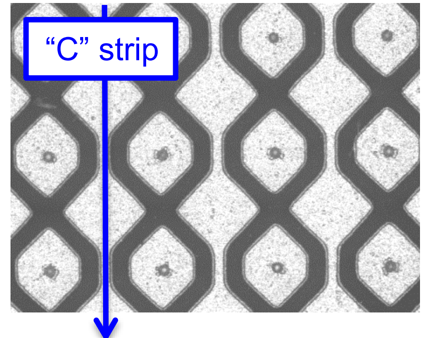


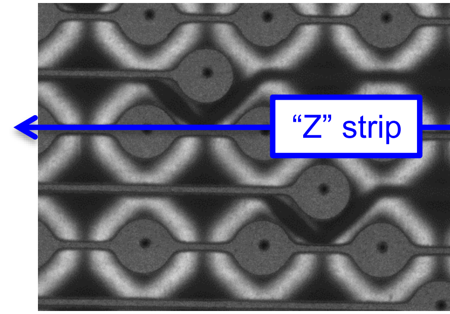
# THE AMT PROTOTYPE

ASACUSA required several innovations:

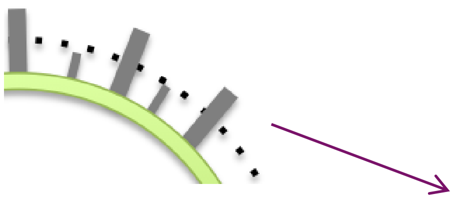
- -High curvature cylindrical bulk
- -Intermediary pillars structure
- -2D C-Z readout pattern
- -Gas distribution through aluminum frame

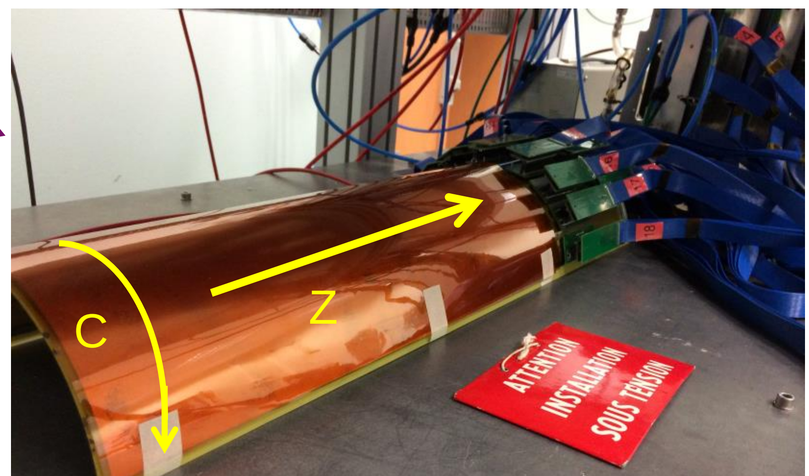



Readout pattern (top)



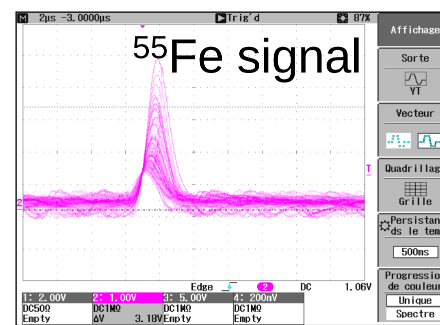

Readout pattern (bot)






10 cm radius prototype bulked @ Saclay january 2014

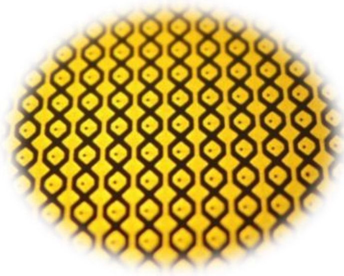
Characterization with cosmic rays and $^{55}$Fe source

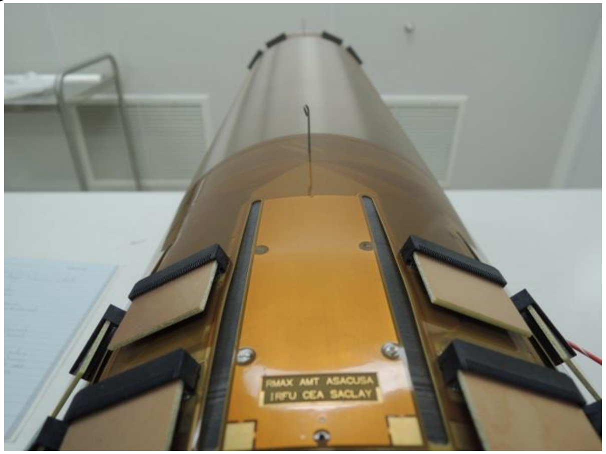


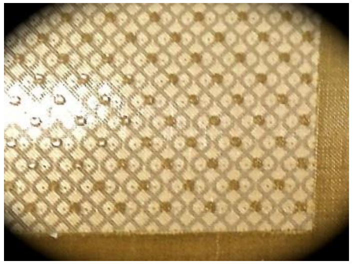
# THE AMT DETECTORS - PRODUCTION

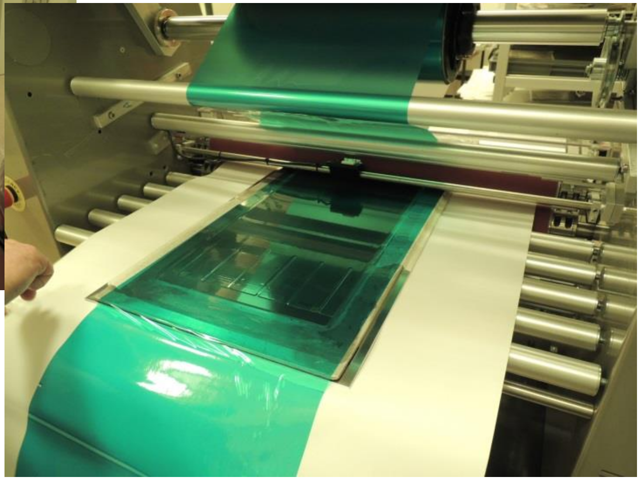
Spring 2014: production of 4 detectors with the final design

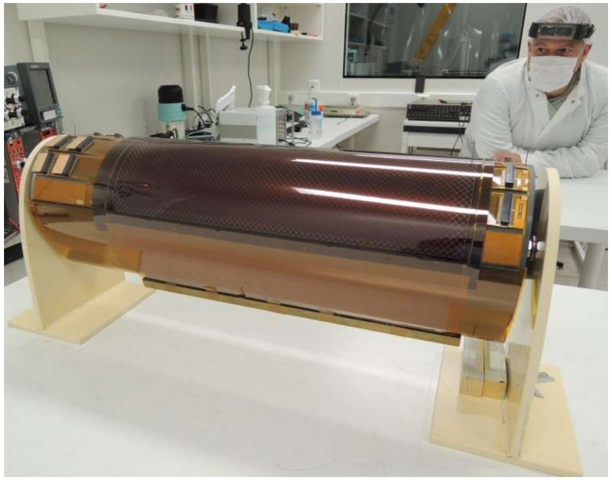
- Prototype home-made @Saclay
- Final detector PCB bulked @ CERN





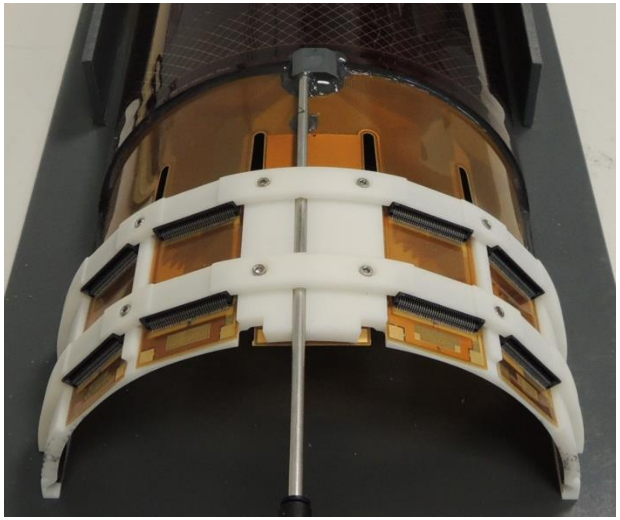




# THE AMT DETECTORS FINAL DESIGN

- 2 Nominal detectors

$R_{MIN}$ : 60cm x 85 mm radius
$R_{MAX}$ : 60cm x 95 mm radius



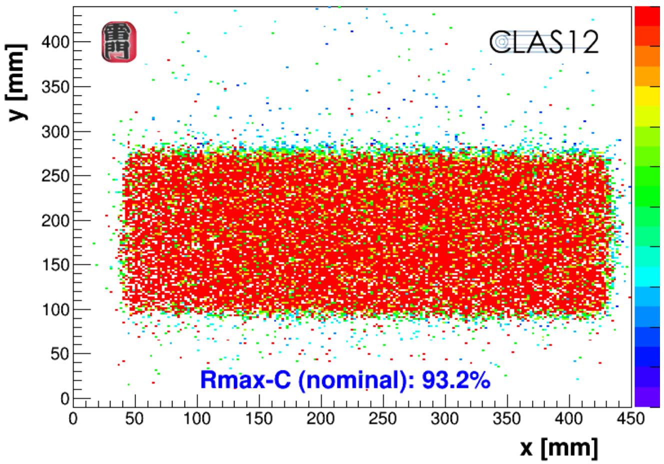
- 3D printed structure (white)
- Cutout flaps for a better deformation at the connector level
- Gas distribution through aluminum

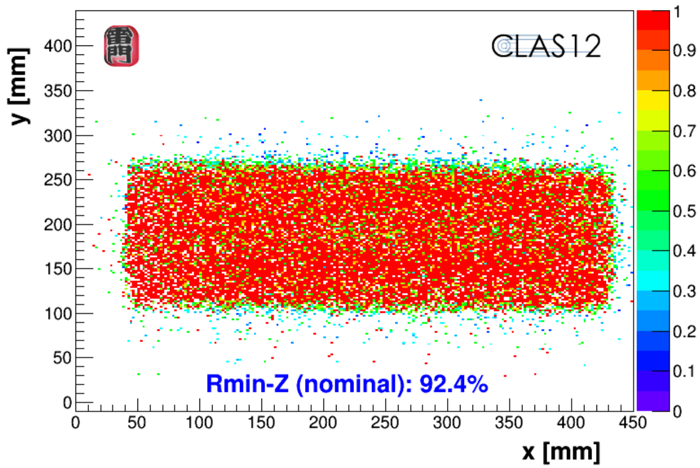
# THE AMT DETECTORS – TESTS WITH COSMIC RAYS

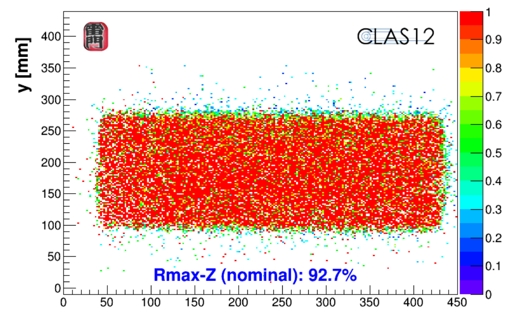


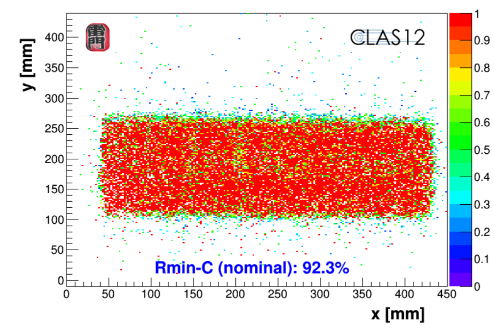
Running conditions:

- Gas mixture Ar/i$C_4H_{10}$ 95/5
- High voltage: $HV_{MESH}$ = 440V, $HV_{DRIFT}$=840V
- Final DREAM readout electronics is used
- Significantly better shielding of detectors



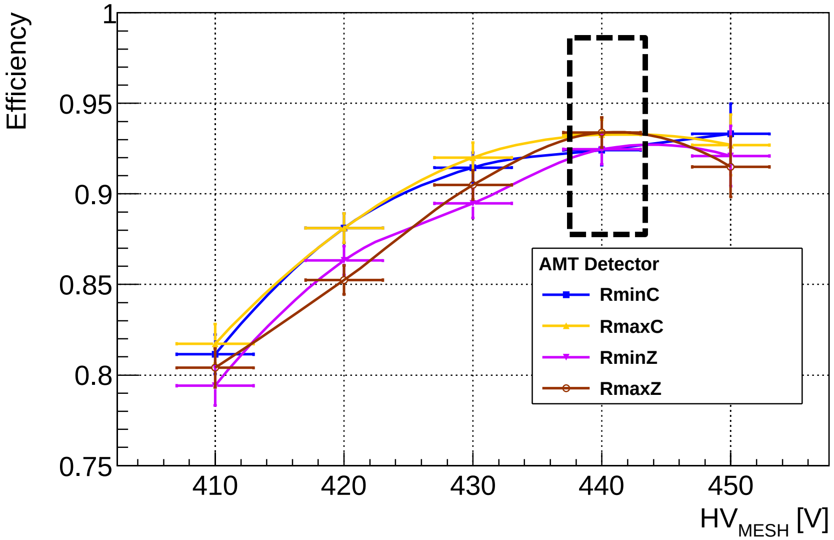

Plot made using only 0.5 day of data cosmic test bench @ Saclay -Building 546

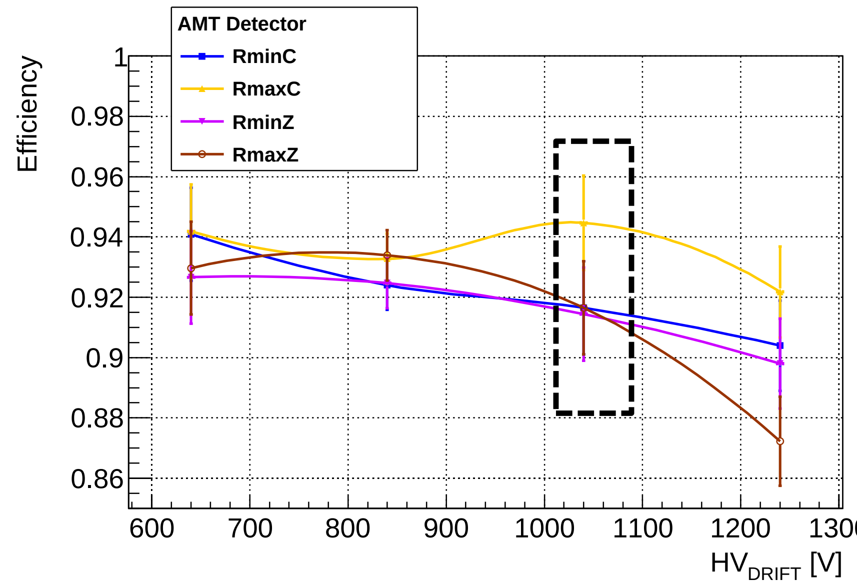
Efficiencies of ~92% per projection

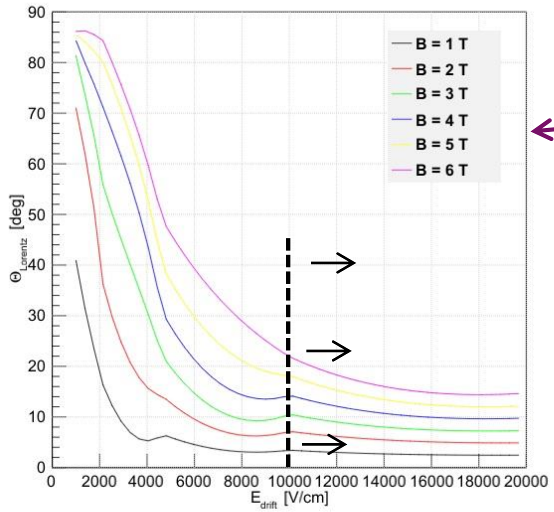
=> Very good performances for the 4 AMTs

# THE AMT DETECTORS – PLATEAU

Gas mixture : $Ar/iC_4h_{10}$ 95%/5%



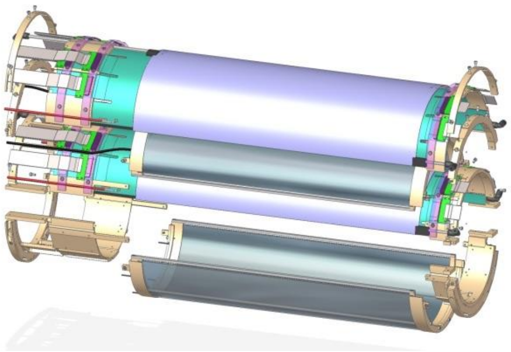



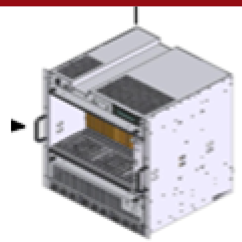

⇒ Effect of magnetic field visible
Drift field is increased for data taking

A DREAM ELECTRONICS….

# READOUT ELECTRONICS - DREAM -

## Electronic requirement

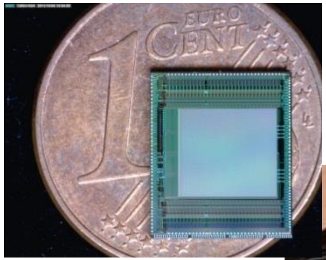




- Space constraint
- High input capacitance: 100 to 200 pF
- 50 kHz particles trigger rate
- Channel number: ≈ 2500

- **NEW ASIC**: **DREAM** [**D**ead-timeless **R**ead-out **E**lectronics **A**SIC for **M**icromegas]

## Layout & case

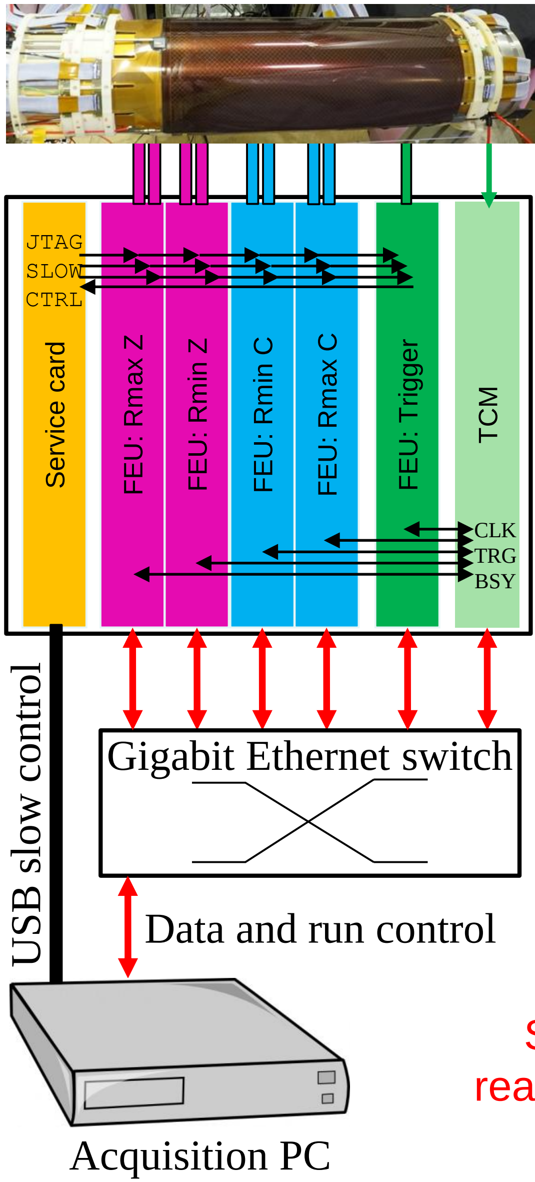


- Technologie: AMS CMOS 0,35 µm
- Surface: 8,6 x 7,5 $mm^2$
- Transistors Numbers:# 700 000
- Case: LQFP 128 (14 x 14 x 1,4 mm)
- 2014: 1600 buit and tested

DREAM a versatile ASIC Suitable for different detector types particularly well adapted for high capacitive detectors

# AMT DETECTOR READOUT

## BASED ON CLAS12, MINOS AND MORDICUS EXPERTISE




Detector links

FE crate with 5 FEUs & TCM

64-channel 1.5m long micro-coaxial low 70 pF capacitance cables

TCM Board

64-channel Dream ASIC & 512-channel fronted unit FEU

Requirements

- ~3000 channels
- 10 kHz annihilation rate
  → 50 kHz particle rate

Extensions

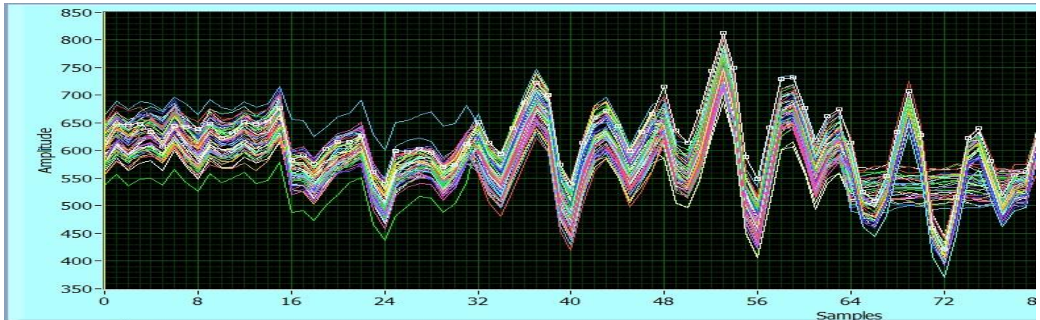
- PMT readout
  → Used during data taking
- Self-trigger capability
  → tested

**Embedded functionalities :**

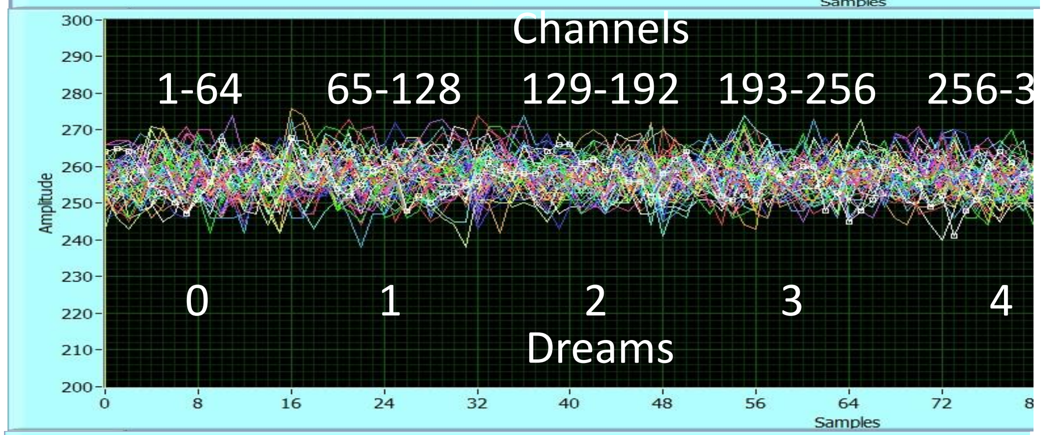
Protections against sparks
Amplification, shaping, sampling
pipeline & buffering, self-triggering
Digitization
pedestal equalization,
coherent noise subtraction,
zero suppression,

Scalable readout system allowing increase of readout rate, data throughput, number of channels

# IN SITU OPERATION

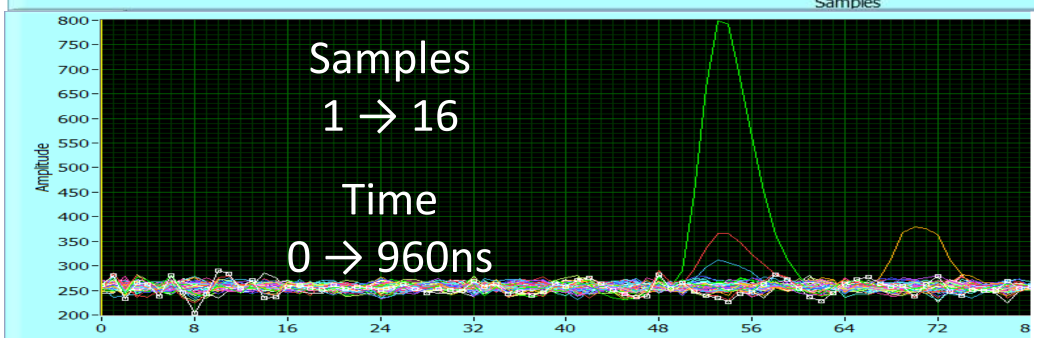



1°) Raw pedestal run revealing severe coherent noise induced by the CUSP magnet




2°) Pedestals after coherent noise subtraction

Resulting noise level: ~1700e$^{-}$ (ENC)



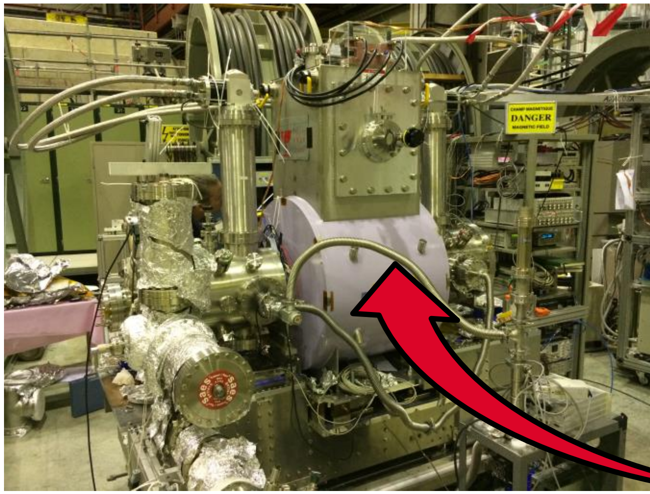

3°) Example of a cosmic event

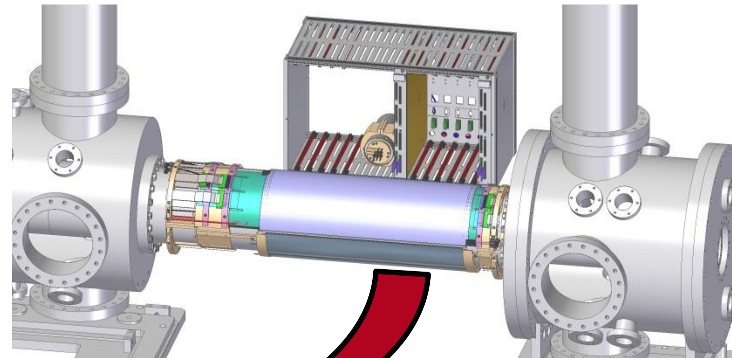
**Operation at high annihilation rate validated during the 2014 data taking**

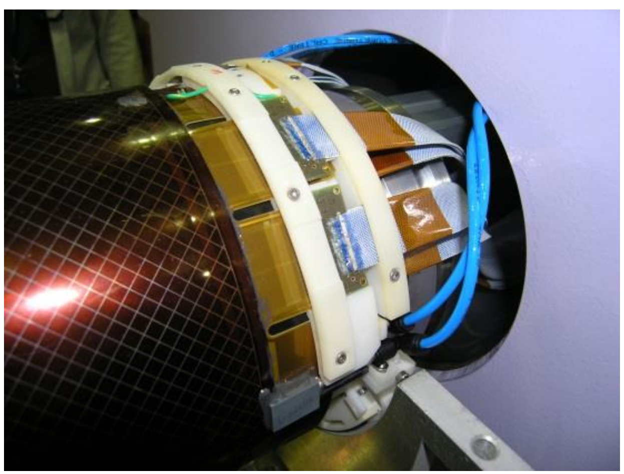
# AMT INSTALLATION
# CERN- AD BUILDING-193

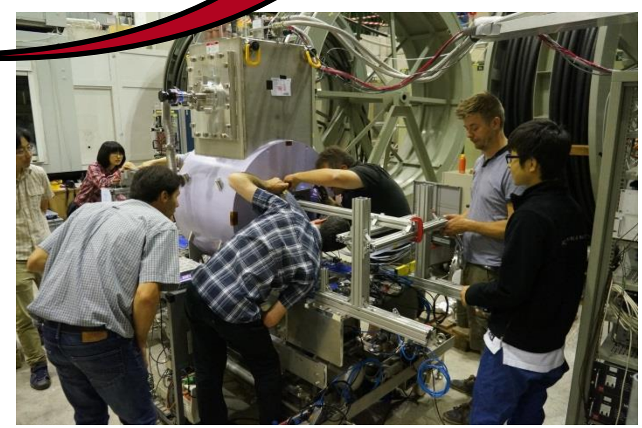
# THE AMT IN SITU

## The AMT inside the trap, installed in August 2014





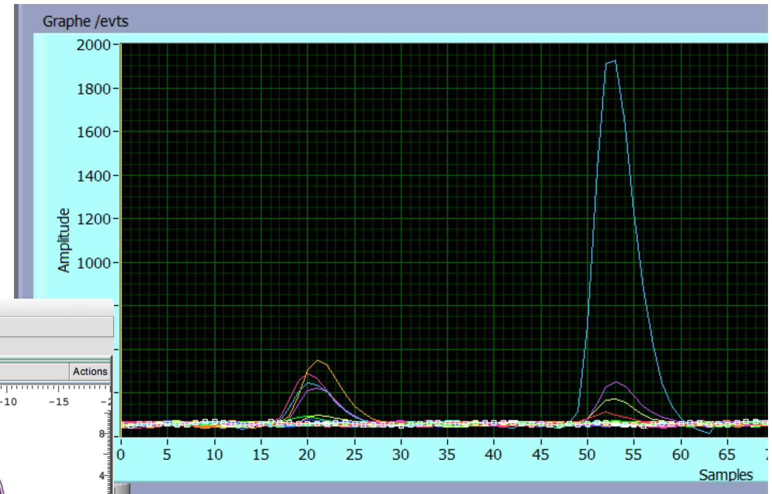


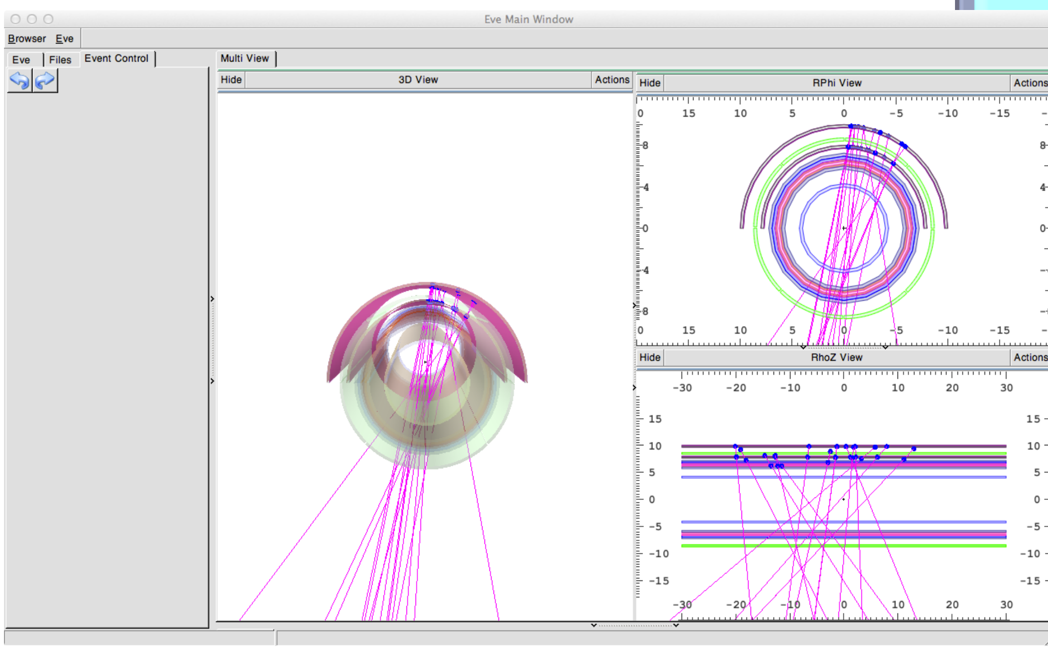
# COSMICS EVENTS

Very large noise in the magnet due to pumps, CUSP infrastructure(valves…)

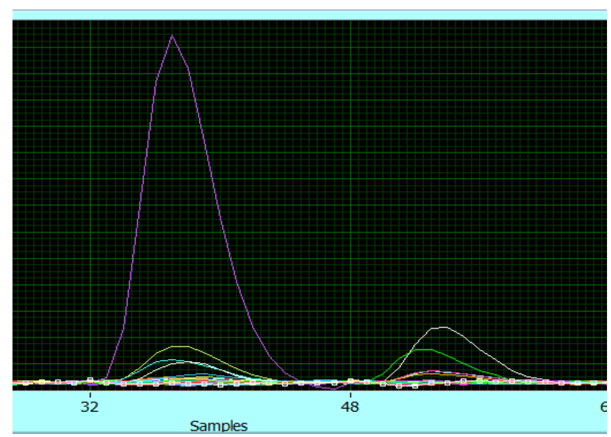
Cosmic trigger using the 8 scintillators tiles

Reconstruction and Tracking ok



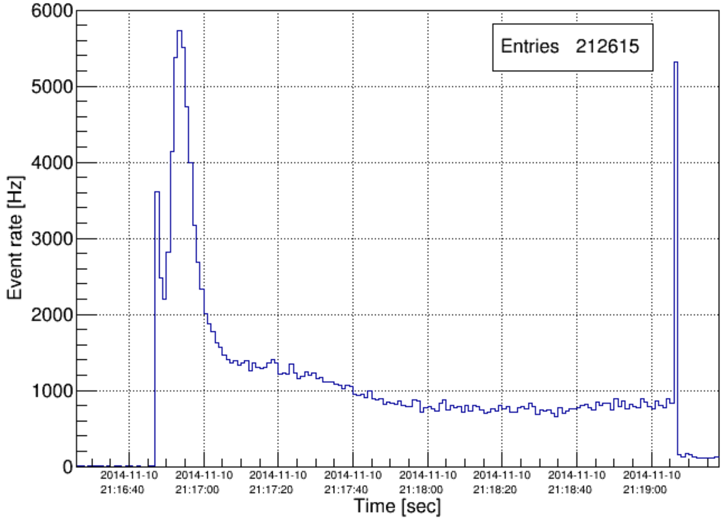



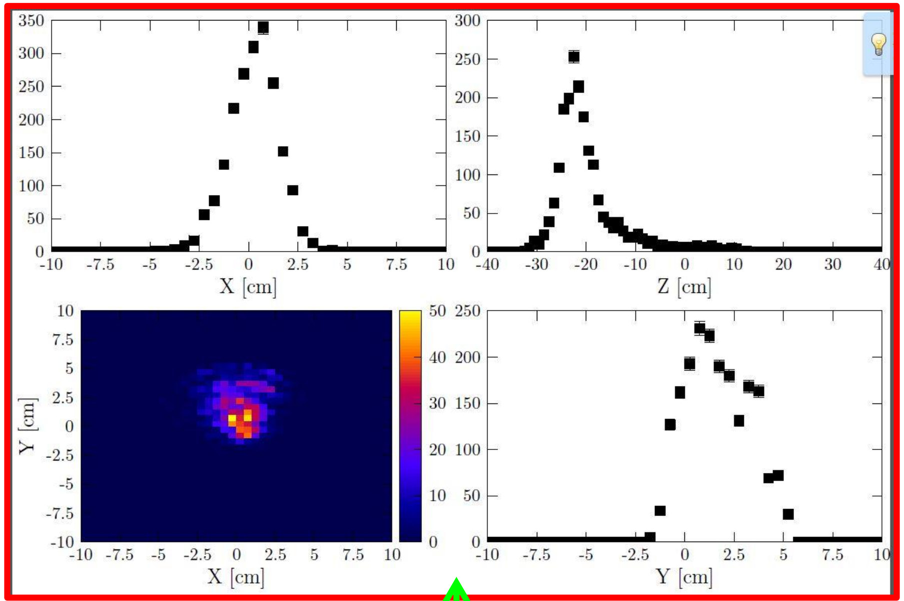

Cosmic ray event display @ CERN (B. Radics)



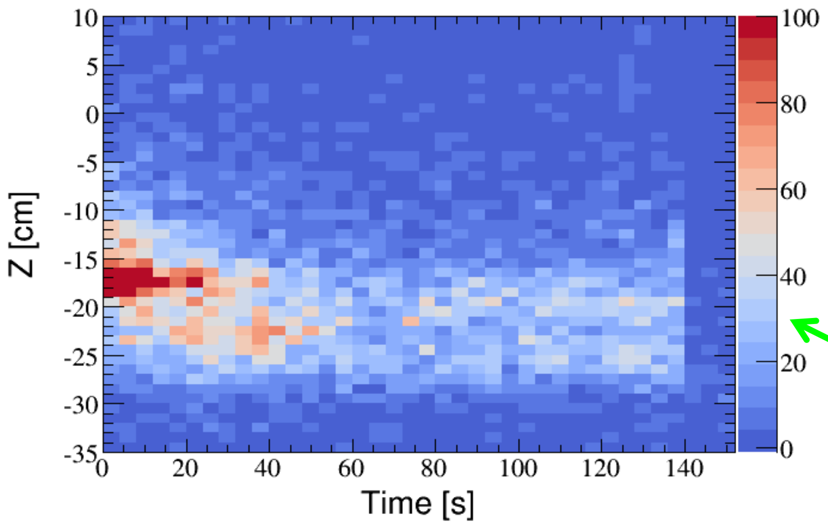
# RESULTS

## 150 eV antiproton energy




2014 calibration data with trapped antiprotons 3D positions reconstruction. They fit very well with the position of the trapped antiprotons.




Axial annihilation position as a function of time from the start of the trapping

# ACKNOWLEDGMENT

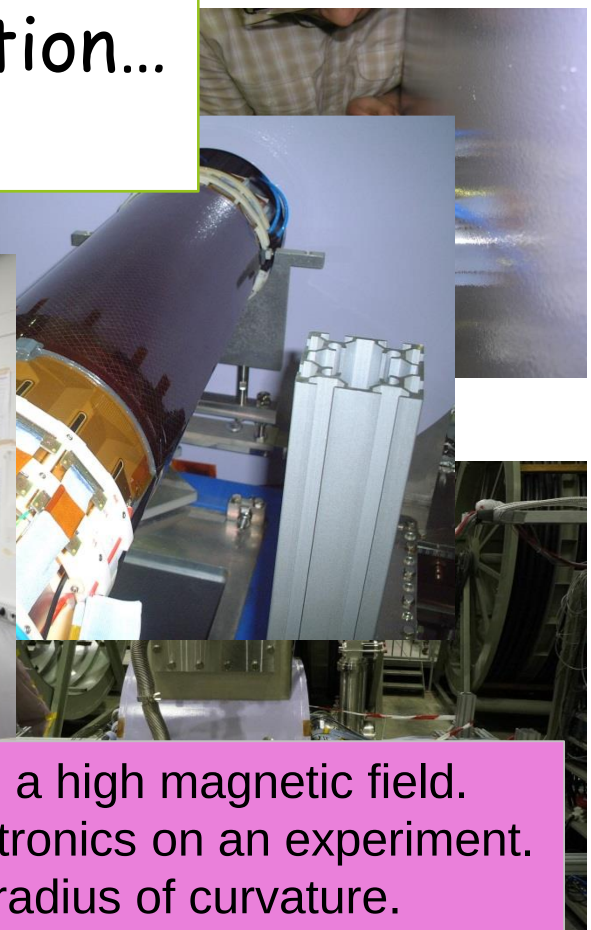
**IRFU**:
Stephan Aune
Pascal Baron
Michel Boyer
Denis Calvet
Frederic Château
Michel Combet
Remi Granelli
Serge Hervé
Pascal Le Bourlout
Irakli Mandjavidze
Olivier Meunier
Sebastien Procureur
Marc Riallot
Bertrand Vallage
Maxence Vandenbroucke

≈ 2,6 Man-Year

**RIKEN**:
Yasunori Yamazaki
Balint Radics

Irfu
Institut de recherche sur les lois fondamentales de l'Univers

# Thank you for your attention…



- end of january 2014 : PCB final design
- mid-february 2014 : Mechanical
- end of march 2014: Mechanical
- april 2014: PCB ready
- may 2014 : Bulks ready
  Bulks equip
- june 2014 : Cosmic test
  electronics at Saclay
- august 2014 : Installation at CERN

1st time:operating in a high magnetic field.
1st time:Dream electronics on an experiment.
1st time:such small radius of curvature.
1st time: 2D C-Z readout pattern.