Development of a new Gaseous Proton Recoil Telescope

L. MATHIEU (LP2iB/CNRS)

- **WP1:** Developments of new innovative detector devices
  - **Task 1.1:** Innovative devices from fission cross section to fission products decay studies
    - Subtask 1.1.1: fission cross sections
      - Subtask subdivision: Development of two new detector devices:
        1.1.1_1: LP2i-Bordeaux: Gaseous Proton Recoil Telescope (GPRT)
        1.1.1_2: CEA: Micromegas-based “transparent”detector with XY readout and TOF capable electronics

- **D.1.1 (M48+6):** *“Report on the study and construction of new devices for precise fission cross section measurements”*

I- Motivations

Cross section measurement relative to $^{1}H(n,n)p$

Goal: to provide accurate Nuclear Data free from $^{235}U(n,f)$ correlation

Mean: conversion of neutron flux into proton flux through H-rich radiator irradiation

Challenge for E_n < 1 MeV

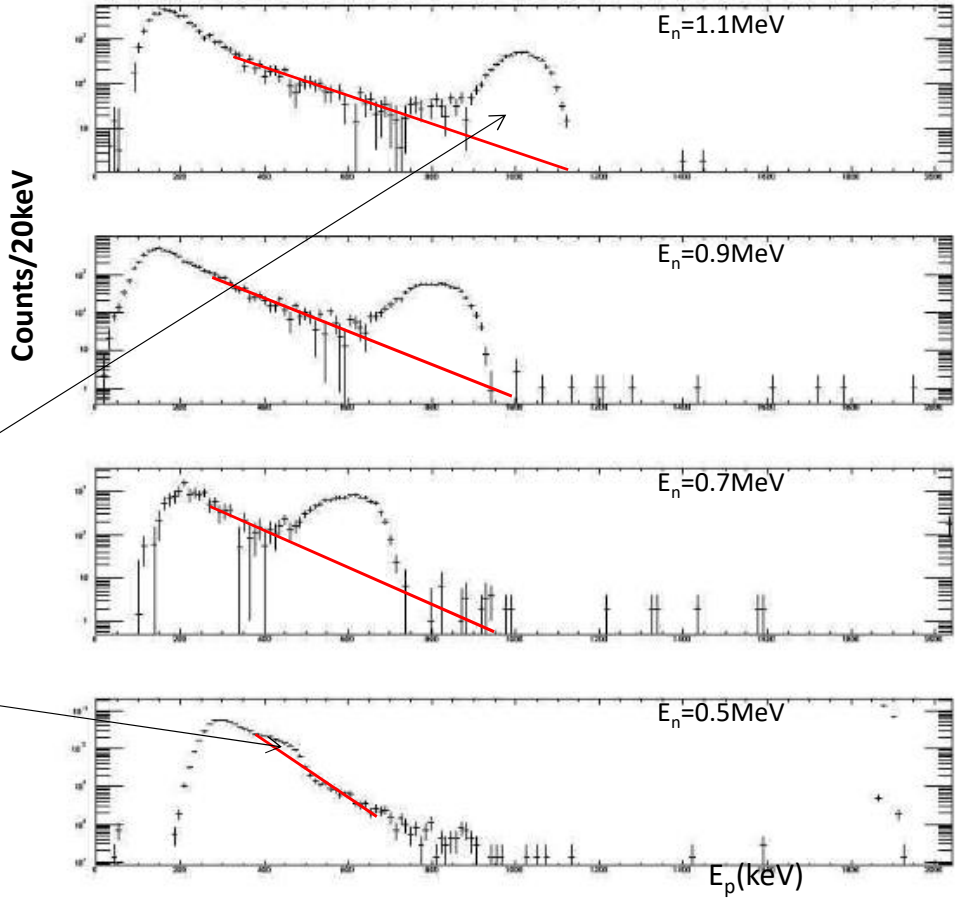
Recoil protons are detected:
- downstream the radiator
- with a small aperture angle to form a proton peak ($E_p \sim E_n$)

Low energy: high background coming from γ and e^-

Impossible to count recoil protons with a good accuracy

A new detector is required with a low-sensitivity for e^-/γ

➡ **Gaseous Proton Recoil Telescope (GPRT) development**



P. Marini et al., Nucl. Instr. and Meth. A, 841 (2017)

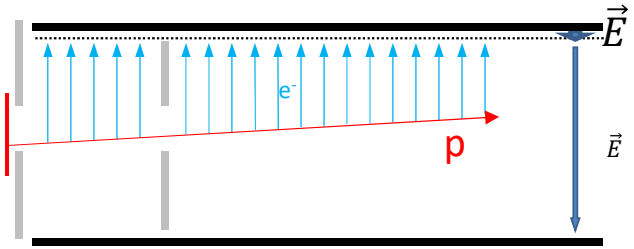
II- Gaseous Proton Recoil Telescope

GPRT features

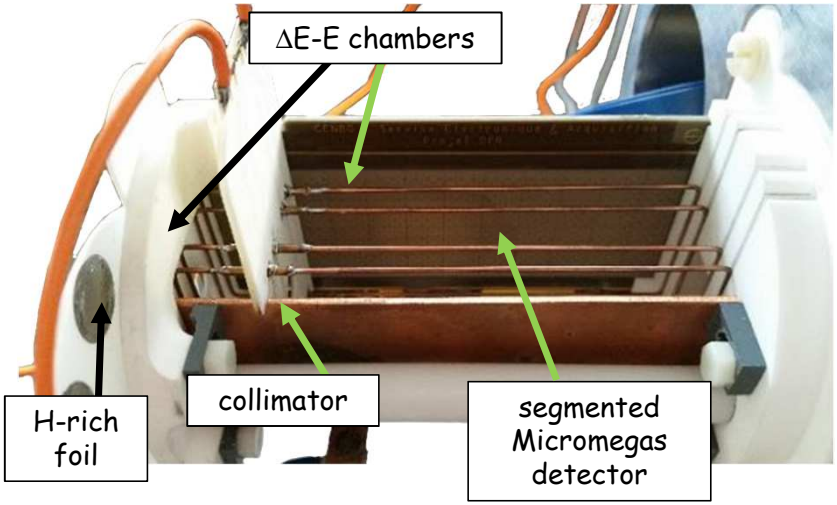
Gas detector:
- to reduce γ/e⁻ sensitivity
- gas pressure adapted to the neutron/proton energy
- gas mixture 70%N_2-30%CO_2

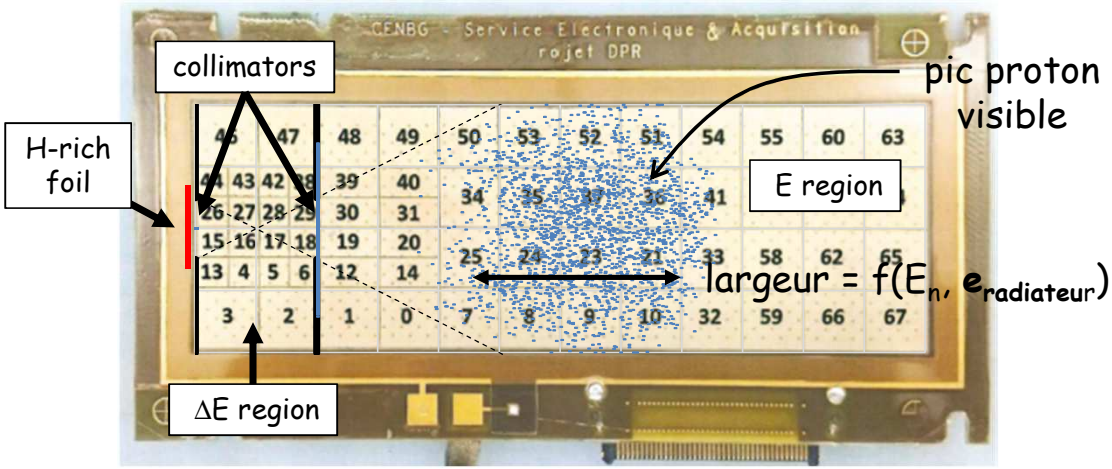
Two chambers with collimator:
- to select only forward protons (E_p ~ E_n)
- precisely define the geometrical efficiency

Micromegas detector:
- for signal amplification
- high range in gain, good radiation hardness, good timing



Segmentation + slow gas: Time Projection Chamber
- 3D track reconstruction
- useful for parasitic track rejection
- scattering angle => initial neutron energy





II- Gaseous Proton Recoil Telescope

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GPRT performances

Track reconstruction:
- works for alpha particles or recoil protons
- sees also some cosmic events (to be discriminated)

Low sensitivity to γ/e⁻:
- low energy deposition from e⁻ in the gas
- trigger functions to catch real tracks and not isolated events
- **low sensitivity achieved**

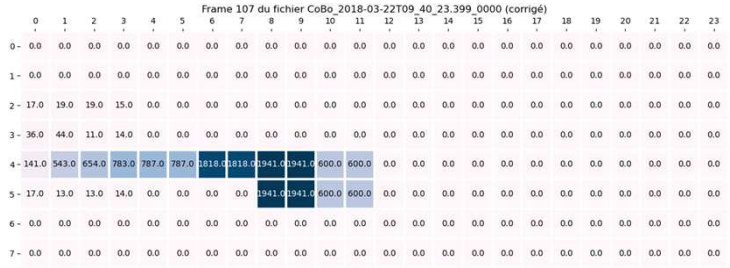
Neutron discrimination:
- proton tracks from direct vs scattered neutrons
- discrimination based on track length

Low detection energy limit:
- limitation due to minimal acceptable range and radiator thickness
- track for recoil protons as low as 200 keV

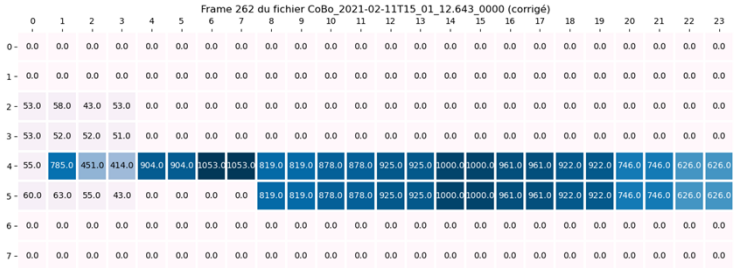
Good electric field behaviour:
- electric field uniformity (field cage)
- stable under irradiation (electric charge remover)

General functioning:
- gas regulation
- rotating sample disk

Low energy "recoil proton" track



High energy "direct proton" track



Pre-SANDA GPRT

- Final design achieved (with field cage and electric charge remover)
- Very few tests with the new slow gas mixture N_2-CO_2 (formerly CF_4)
- Only qualitative studies so far

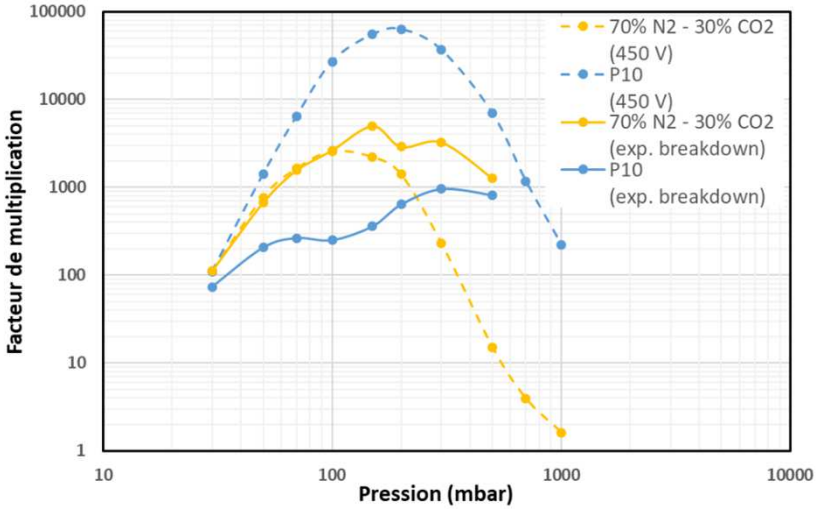
Exploring the operating range *(PhD thesis Carole Chatel)*

Pressure studies and Breakdown voltage:

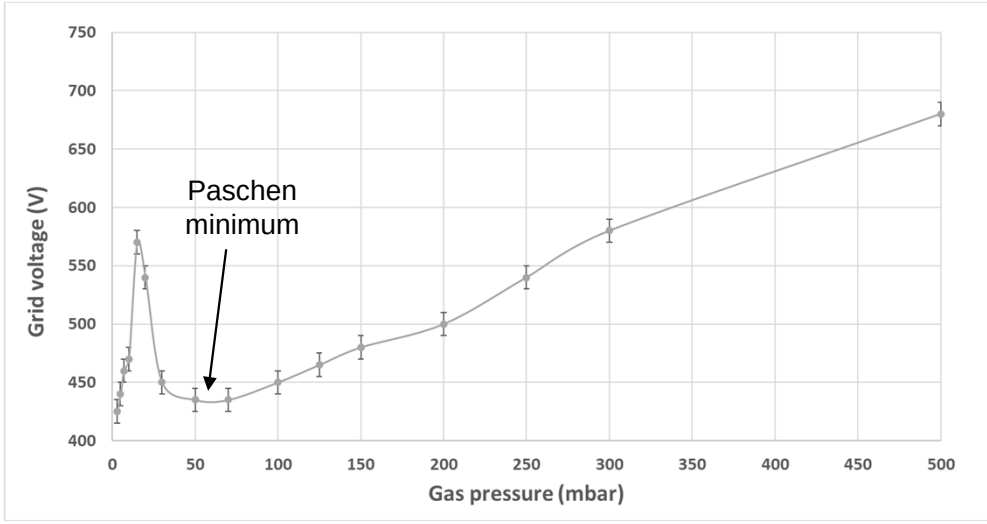
- gas pressure of few 100 mbar for alpha test, but few 10 mbar for recoil proton experiments
- unfortunately in the minimum of the Paschen curve
- an important limit to the GPRT operation, since it limits the Micromegas gain

- better breakdown voltage with N_2-CO_2 than P10
- better behaviour with N_2-CO_2 than CF_4 at low pressure

Calculated multiplication factor vs gas pressure (for constant voltage or experimentally realistic voltage)



Breakdown voltage evolution vs the gas pressure (N_2-CO_2)



Much higher breakdown voltage for N_2-CO_2 than P10 induces higher gain (despite being theoretically less good)

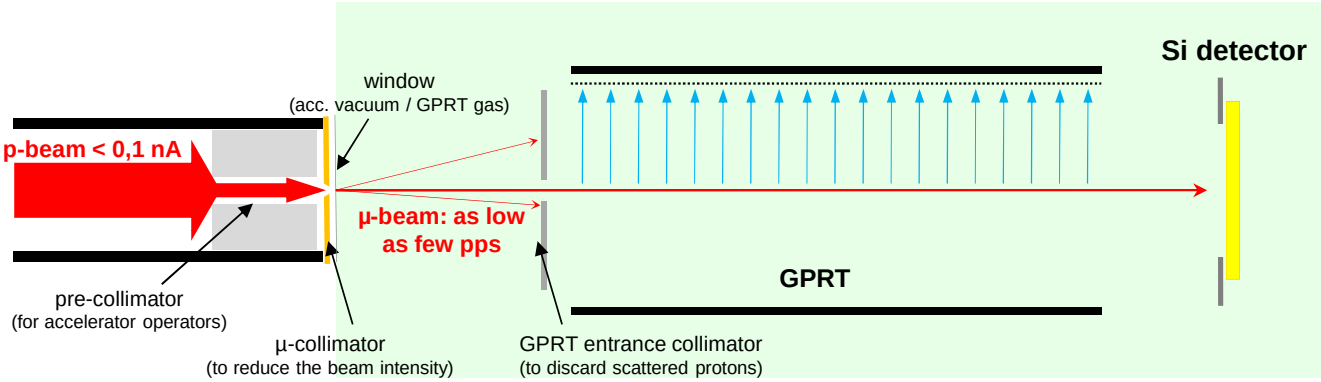
Status:
- Quantitative studies performed
- Suitable operating conditions identified

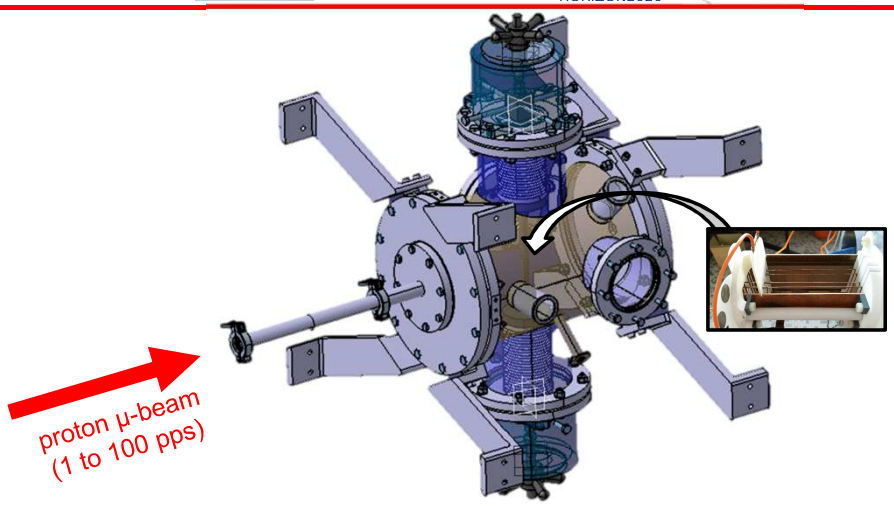
Efficiency measurement *(PhD thesis Carole Chatel)*

Accurate cross section measurement requires :
↳ an accurate flux measurement
↳ which requires and accurate N_p measurement
↳ which requires an accurate efficiency, and so a very well know intrinsic efficiency (ideally 100% as with a Si detector)

Measurements have been carried out to measure this intrinsic efficiency:
- with an alpha source at first ($\varepsilon_{instrinsic}$ ~ 100% but not accurate enough)
- with a direct proton micro-beam :
  . a dedicated chamber has been designed and built
  . the micro-beam was sent in the GPRT and monitored downstream in a Si

Open-access publication: C. Chatel et al, *"Development of a small Time-Projection-Chamber for the quasi-absolute neutron flux measurement"*, hal-04309742





Very "clean" experiments:
- mono-energetic particles
- exact same trajectories
- no intense EM noise

Possible to use the Si as trigger for the GPRT

Tests have shown:
- $\varepsilon_{intrinsic}$ ~ 100% only for very low counting rates
- $\varepsilon_{intrinsic}$ drops as the counting rate rises (~50% for 30 pps)

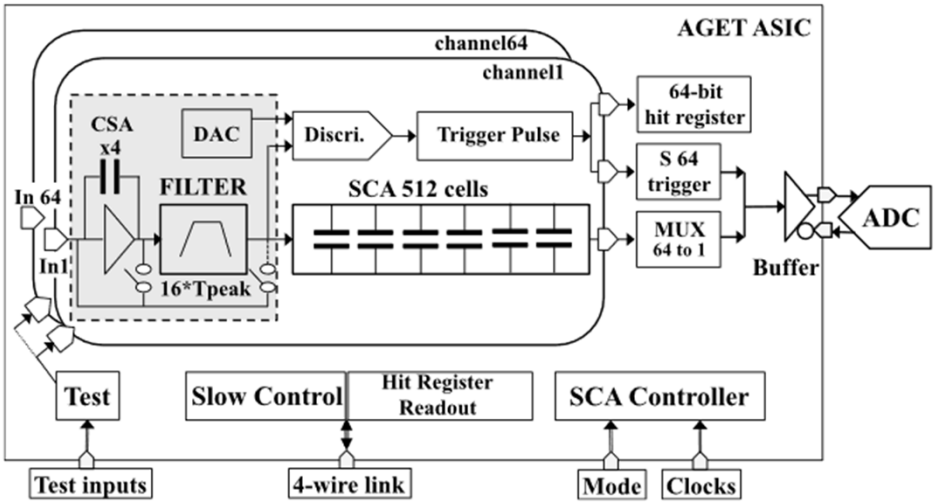
Status:
- Efficiency studies performed
- Dead time issues with the DAQ

Data Acquisition System (DAQ)

SAM system (Single AGET module):
- origin: GET system (General Electronic for TPC) developed by CEA
  1 card = 4 AGET modules = 256 channels
- adapted for 64 channels by LP2i SEA team

SAM characteristics:
- reading frequency: 25 MHz
  read time for 64 channels of 512 time bins: 1.3 ms
- theoretical dead time: 1% at 10 cps, 10% at 100 cps

Workbench tests (following µ-beam experiments):
- measured dead-time of 7.3 ms !
  6 ms are lost during data transfer between DAQ and computer
- **evidence of event loss during data transfer**



E.C. Pollacco et al., Nucl. Instr. and Meth. A, 887 (2018)

Solutions:
- degraded mode *"1 event => 1 transfer"*: no more event loss during transfer
- data reading optimization development *"partial mode"*: fewer channels read => dead time reduction

Status:
- DAQ now has minimal performances to be operational
- Work in progress by the LP2i SEA to study data transfer and optimize DAQ behaviour

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Analysis software

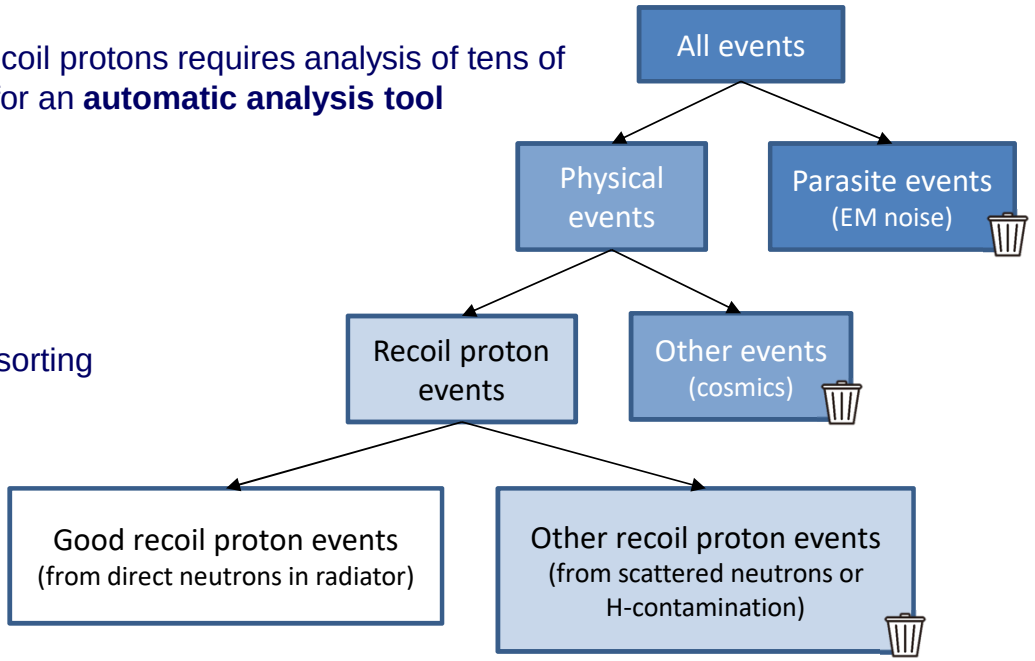
Issue: determining the number of recoil protons requires analysis of tens of thousands of GPRT events ⇒ need for an **automatic analysis tool**

Goal: automatic data sorting
- EM noise
- cosmic events
- parasitic recoil protons

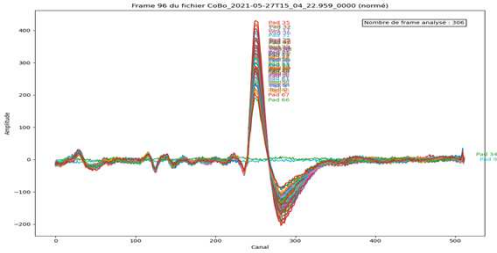
Data correction: required for data sorting
- background correction
- EM parasite correction

Software development:
- data reading
- event visualisation
- data browsing
- data correction

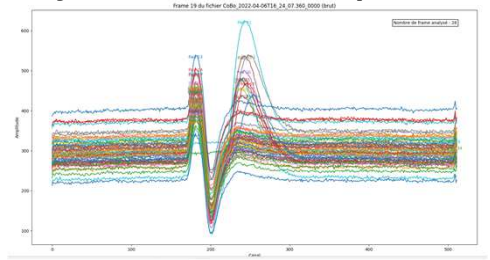
Data sorting tree



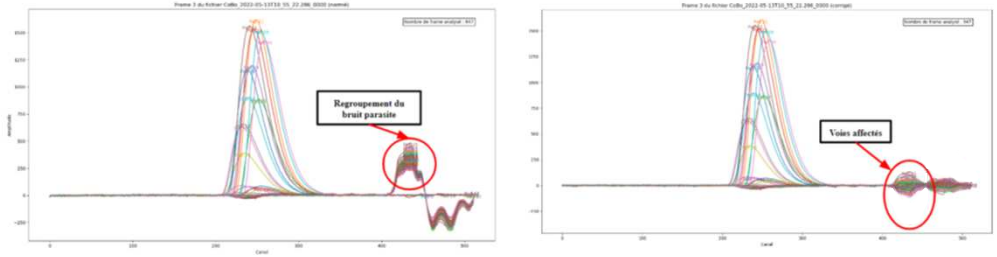
EM parasitic event



Physic event with EM parasite



Data correction



Status:
- Data visualisation & browsing: OK
- Data correction: ~OK but needs improvements
- Data sorting: in progress (but first requires good data correction)

Deliverable and Conclusion

Deliverable

- **D.1.1 (M48+6):** *"Report on the study and construction of new devices for precise fission cross section measurements"*

Status :
Report completed in M54 (on time)

Conclusions included in the report

Detector performances:
- N_2-CO_2 gas mixture quantitative studies
  - . suitable for neutron flux measurement
  - . slow gas enabling 3D track reconstruction
- efficiency measurements with proton µ-beam
  - . dead-time issue revealed !
  - . ε = 100% at low counting rate

Analysis tool: for data sorting
- implemented features:
  - . data visualisation
  - . data browsing
  - . data correction
- work in progress for data sorting

DAQ performances: an efficiency issue which lasted a very long time
- problem identified (incorrect data transfer)
- in "low performance mode":
  - . ε = 100%
  - . dead time manageable

⇒ minimal performance requirements met !

The various GPRT technological building blocks are now validated