Etude et développement de l'électronique cryogénique de lecture des détecteurs à très bas seuil de l'expérience Ricochet pour la recherche de nouvelle physique via la mesure de l'interaction cohérente neutrino noyaux (CENNS)

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RICOCHET
A Coherent Neutrino Scattering Program

ÉCOLE DOCTORALE 52

PHAST
PHYSIQUE ET ASTROPHYSIQUE
UNIVERSITÉ DE LYON

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Outline

- CENNS and Ricochet experiment
- HEMT transistor electronics and noise model
- Setup characterisation and measurements

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- **CENNS and Ricochet experiment**
- HEMT transistor electronics and noise model
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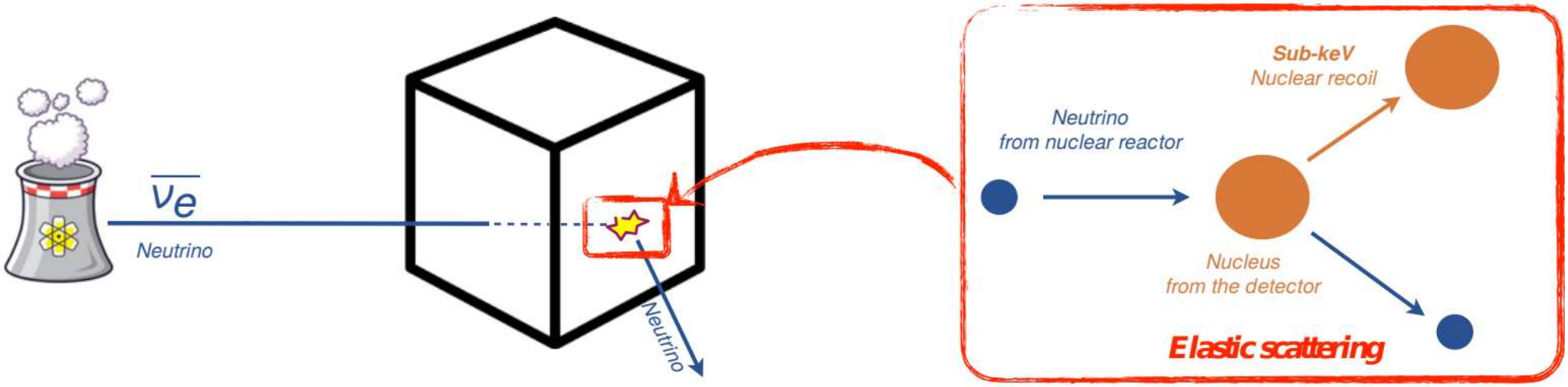
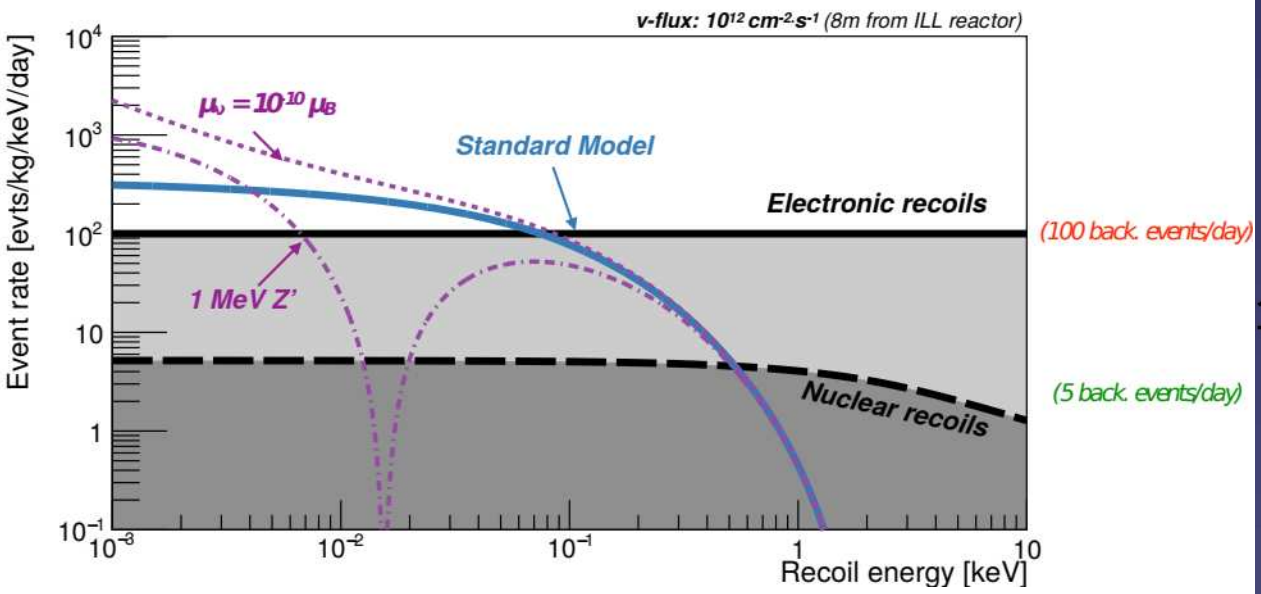
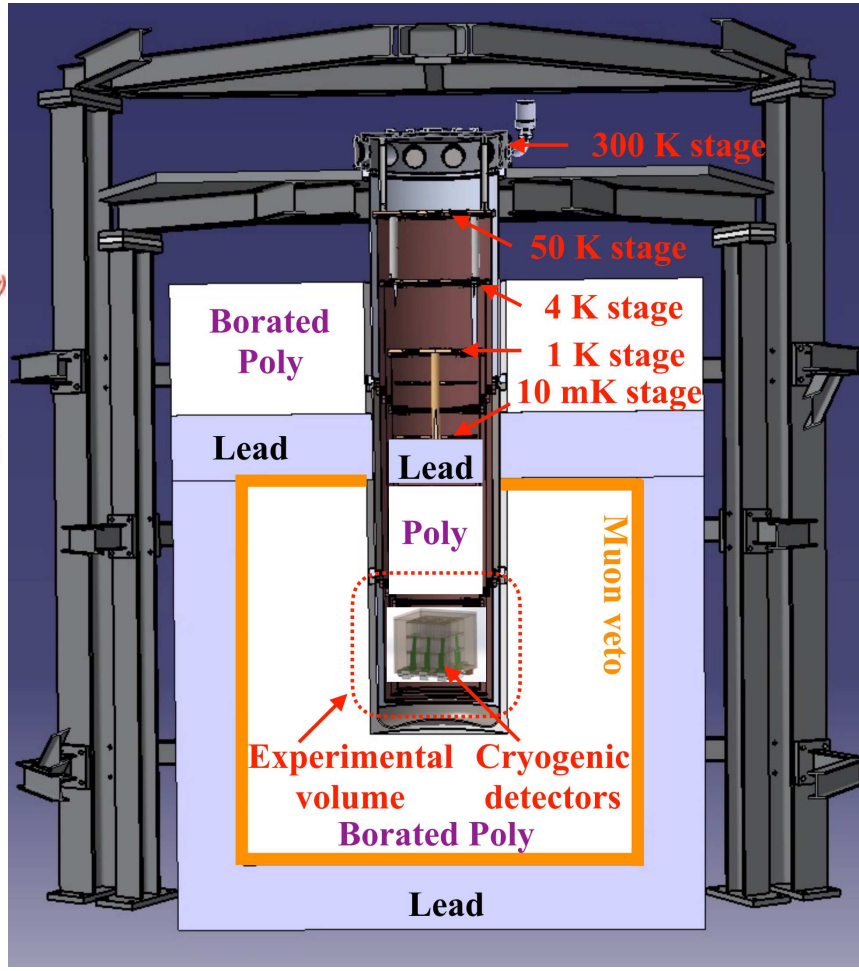
Scientific context



- Coherent elastic neutrino nucleus scattering (CENNS)
- Predicted by the standard model, first measurement in 2017 (COHERENT experiment)
- Any deviation is a sign of new physics

Ricochet experiment





- Threshold in recoil energy of **50 eV**
- Dry cryostat temperature ~ 10 mK
- 8 m from a 60 MW nuclear research reactor (ILL Grenoble)
- Lead/polyethylene shielding and muon veto for background reduction
- Detector mass ~ 1 kg → 15 evts/jour

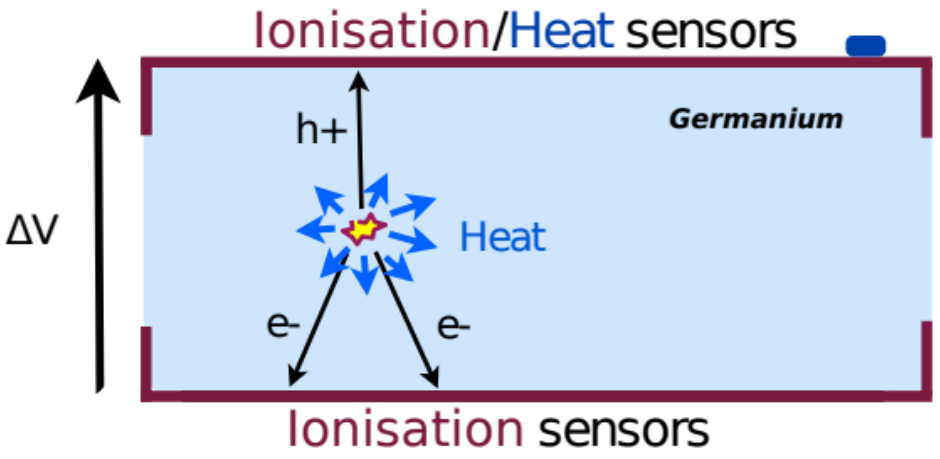
CryoCube detector

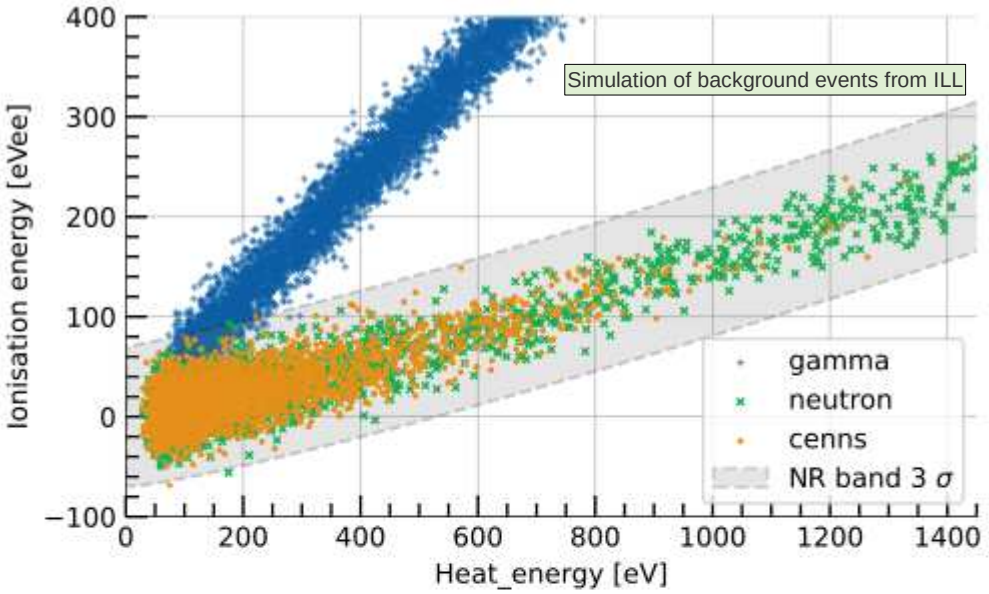
Detection principle:

- Semiconductor detector Germanium T ~ 15 mK same as EDELWEISS-III
- Temperature increase (heat channel) with NTD sensor
- Production of electron/hole pairs (ionisation channel)
- Event discrimination
- Goal :

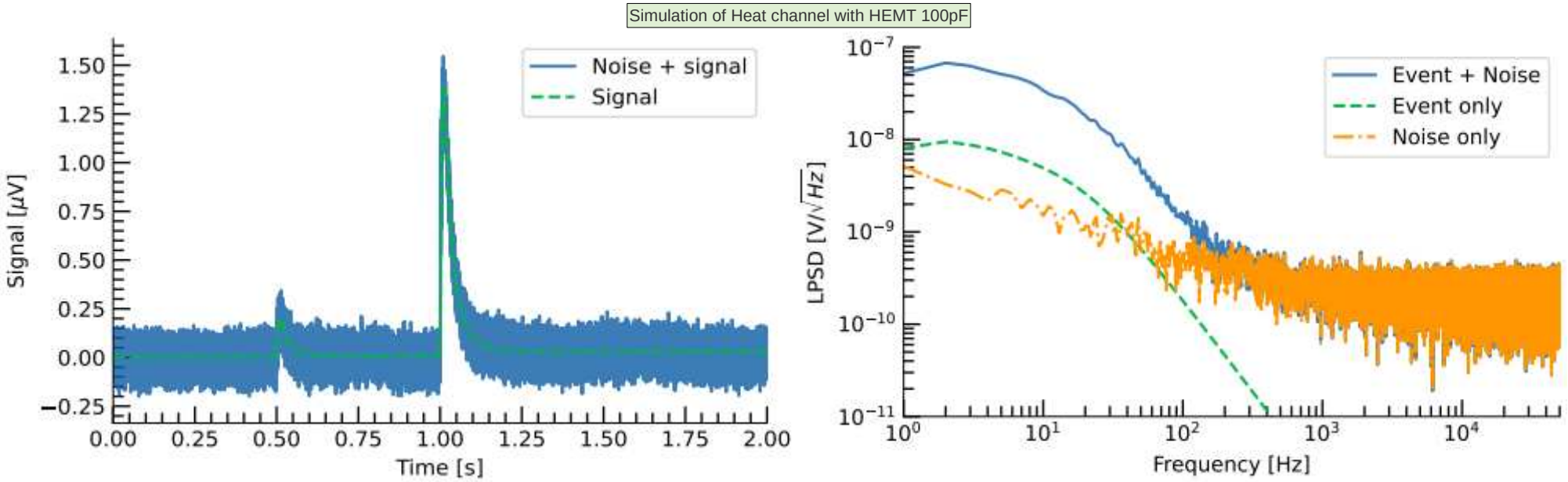
  - ΔT ~ 1 μK, heat energy resolution of **σ_c=10 eV**

  - 10 electron/hole pairs, ionisation energy resolution of **σ_i=20 eV$_{ee}$**





Study of detector signal

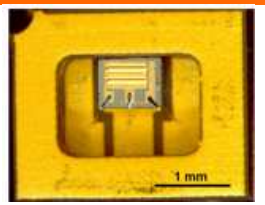


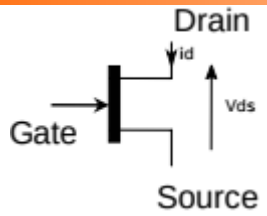
- Passage of a temporal signal in frequency by LPSD (Linear Power Spectral Density)
- Noise spectrum = distribution of the power of a signal according to the frequencies of which it is composed.
- Noise spectrum useful to compare differents datas
- Goal: reduce noise to observe low energy events

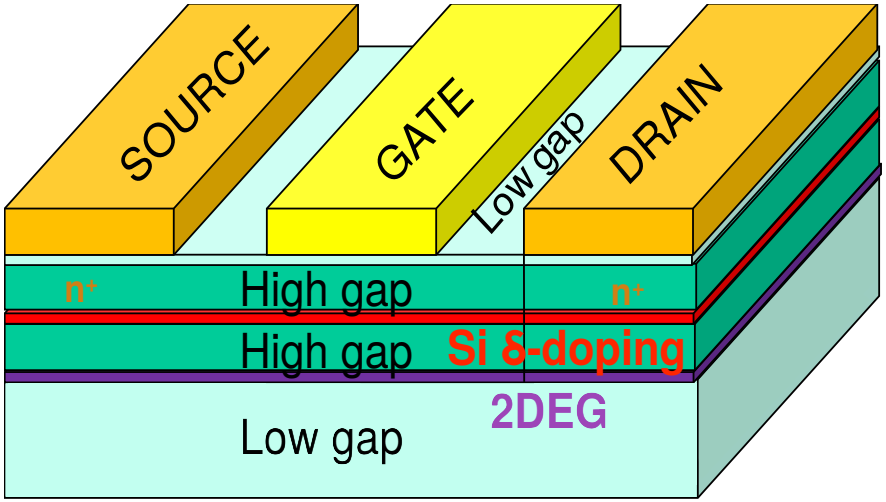
Outline

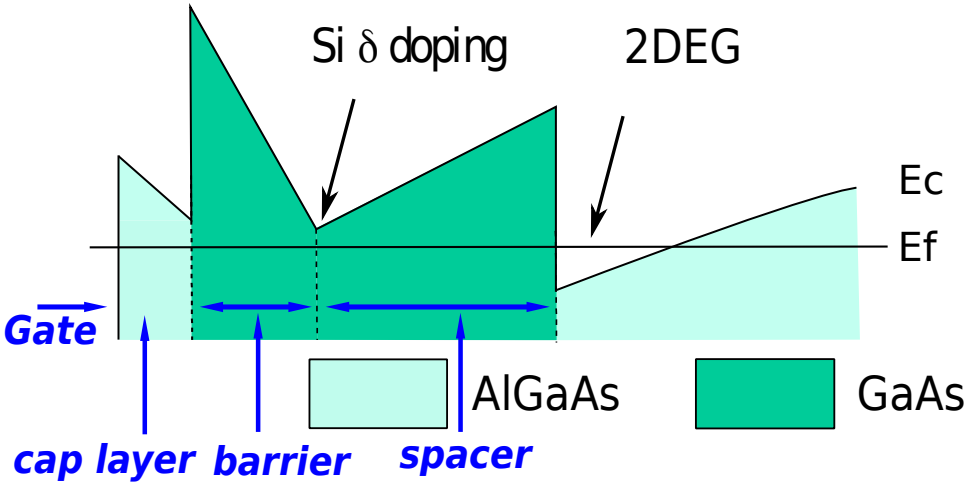
- CENNS and Ricochet experiment
- **HEMT transistor electronics and noise model**
- Setup characterisation and measurements

HEMT (High electron mobility transistor)



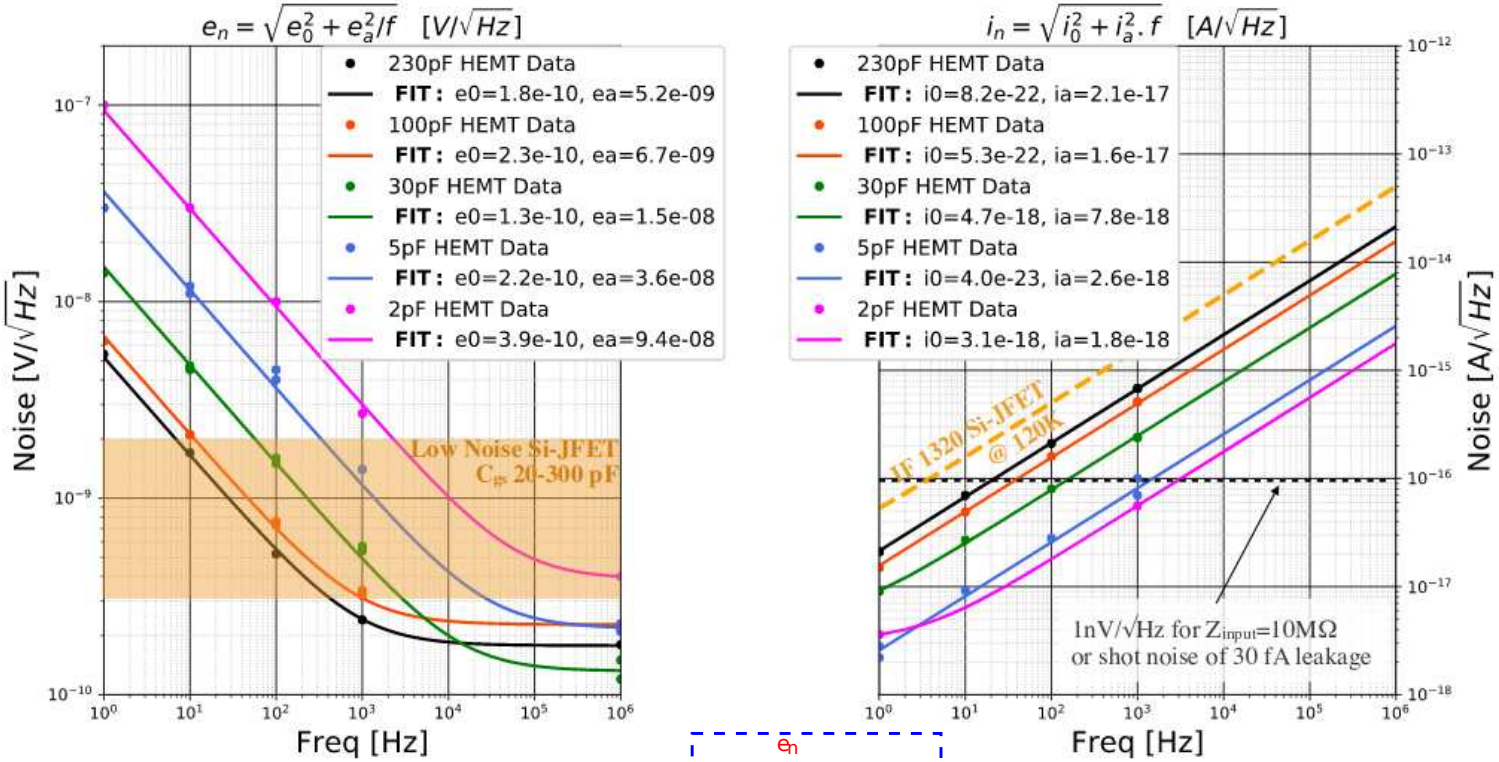






- HEMT are based on 2D electron gas formed at the junction canal/barrier
- HEMT work at all temperature but limited by dissipation (EDELWEISS-III FET 120K)
- HEMT work like a FET, the voltage on the gate changes the electron density ($\Delta V_g \rightarrow \Delta I_{ds}$)
- Source and drain are doped to have direct access to the gas

HEMT noise model

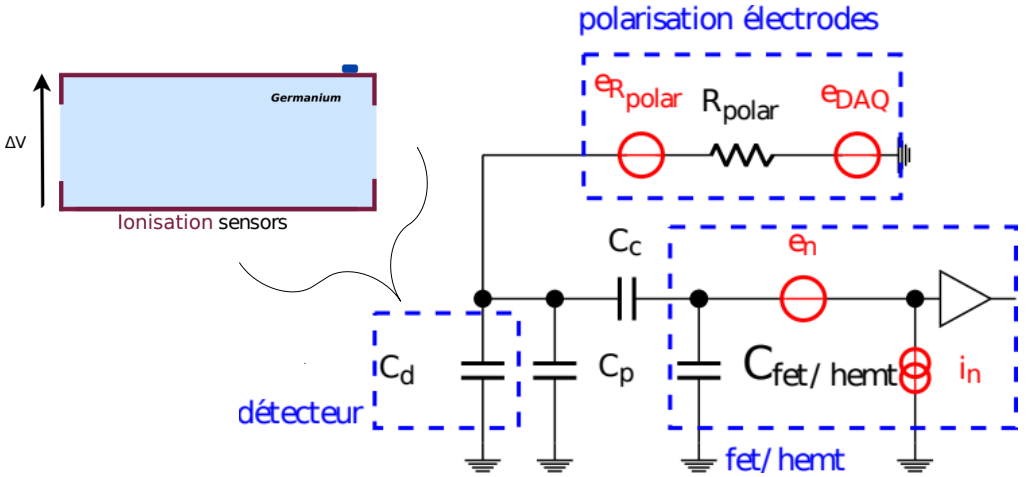


LTD paper : J Low Temp Phys 199

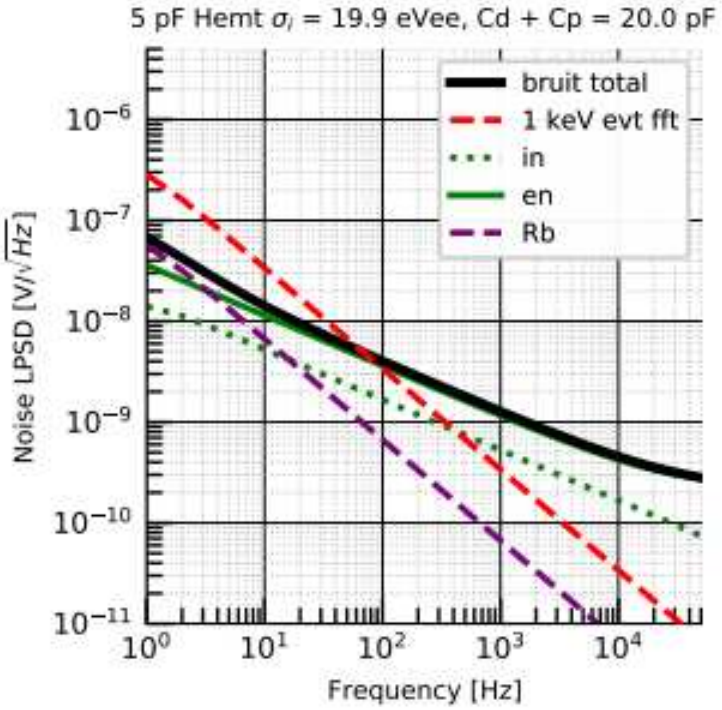
- Model based on voltage noise and current noise
- Measurement with 5 geometries HEMTs studied at 4.2K (C2N/CryoHemt)
- Total noise depends on the impedance Z_{input} of the system (detector)

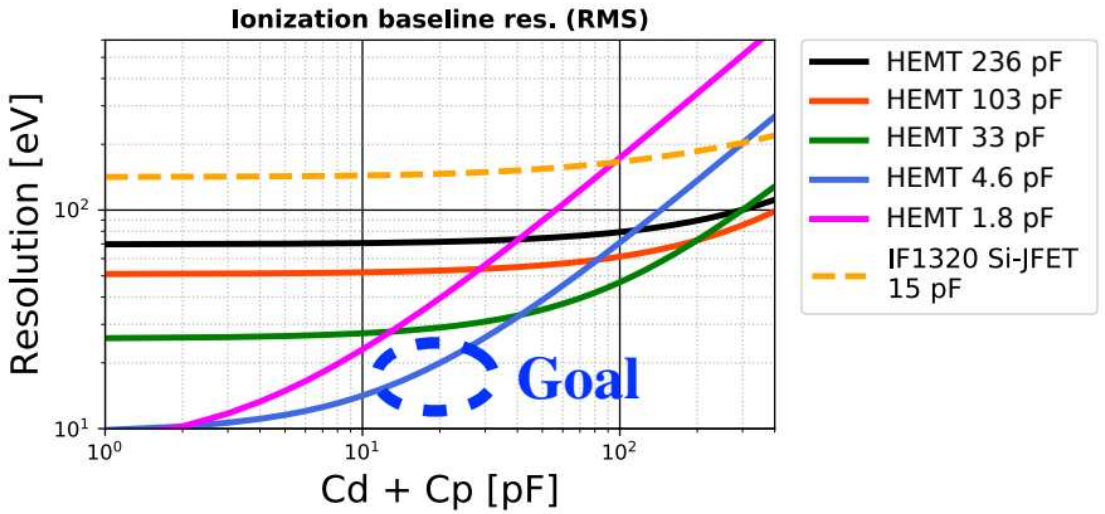
$$e_{tot} = \sqrt{e_n^2 + Z_{input}^2 i_n^2}$$

HEMT model: Ionisation channel

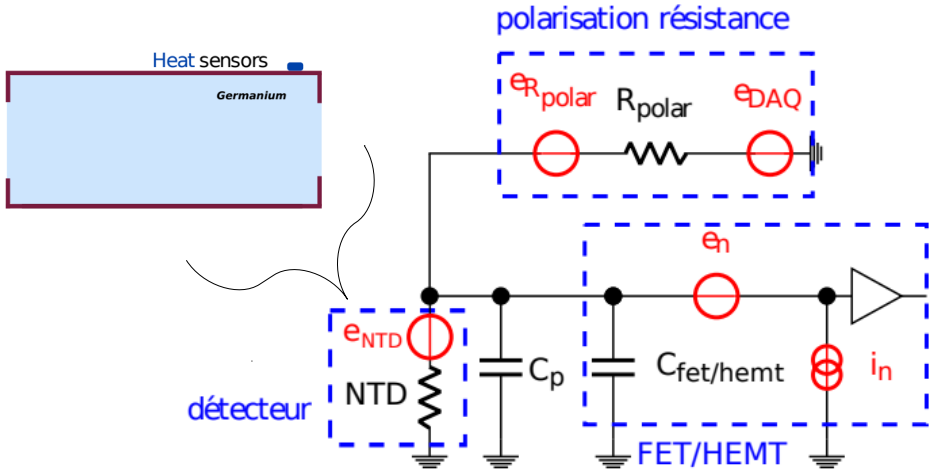


- HEMT noise (voltage, current), polarisation noise
- C_p related to length between HEMT and detector (cable)
- **20eV$_{ee}$** (optimal filter) with **5pF HEMT** and parasitic capacitance **20pF**

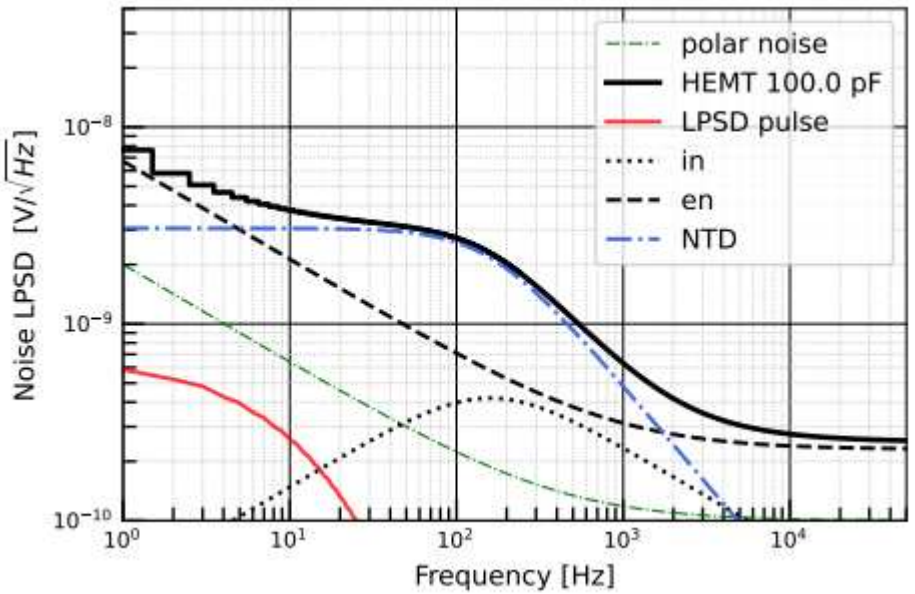


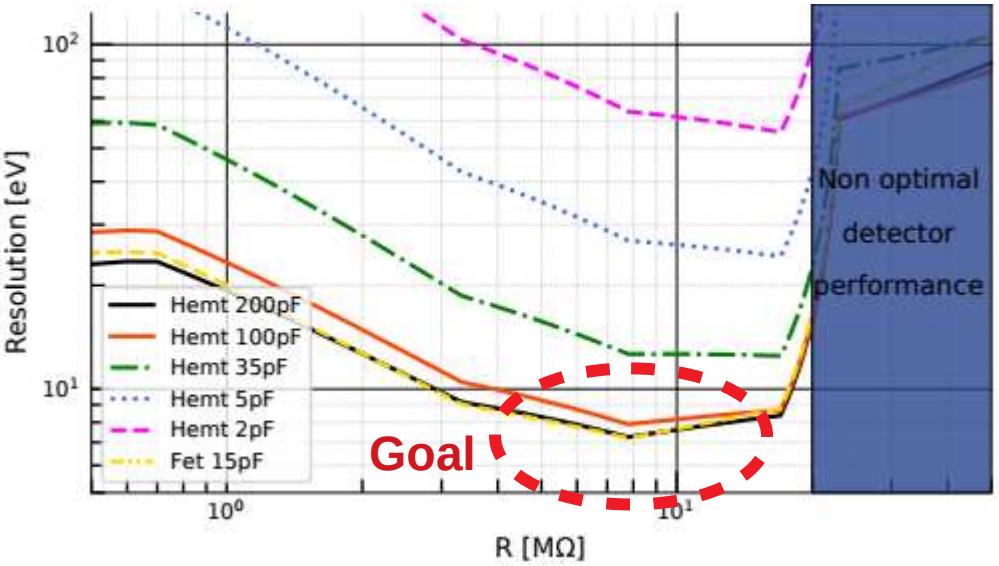


HEMT model: Heat channel



- HEMT noise (voltage, current), detector noise (NTD)
- Sensitivity of heat signal depends on the detector
- **10eV** (optimal filter) with **100/200pF HEMT** or **FET**





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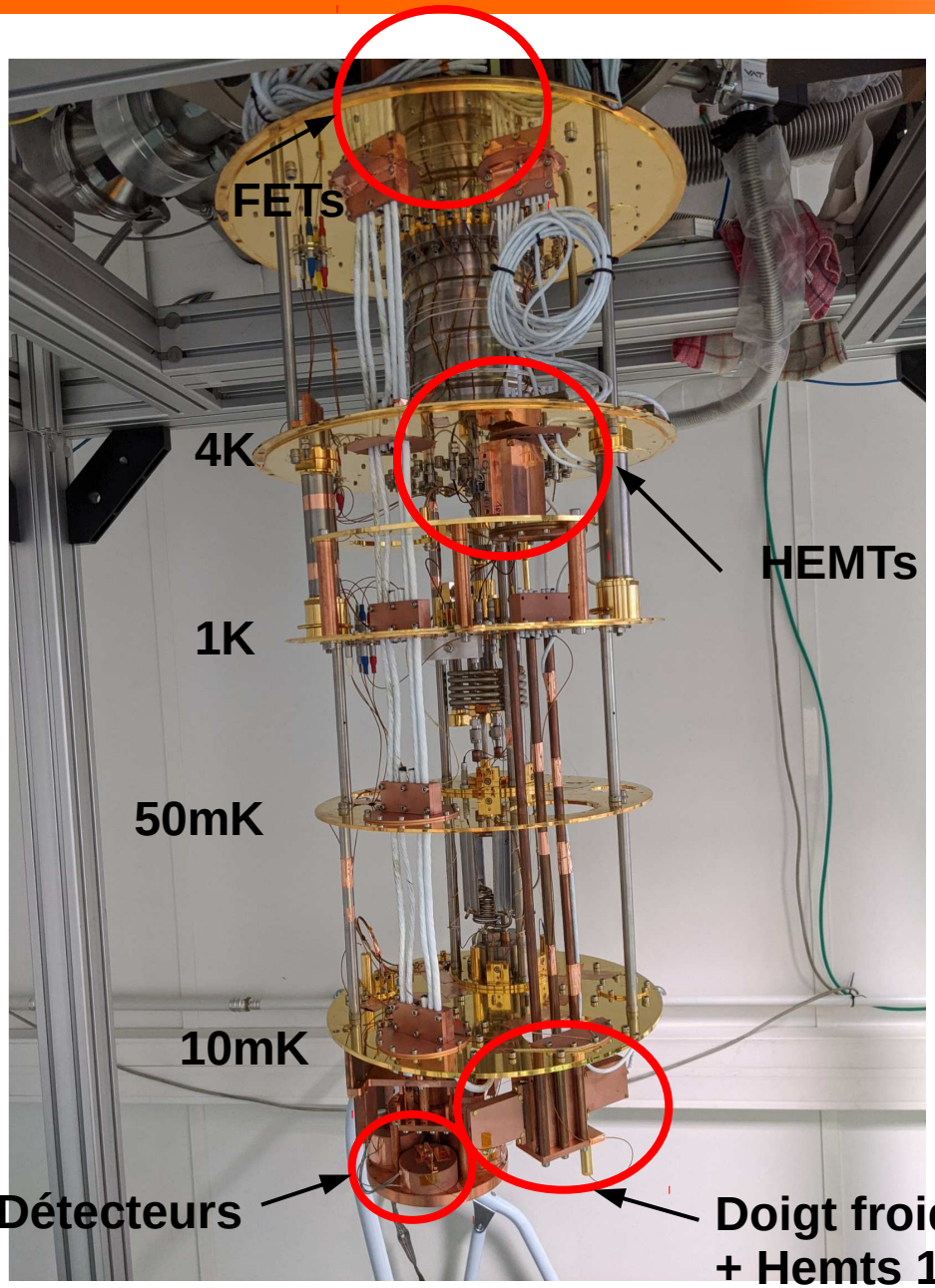
IP2I Cryostat

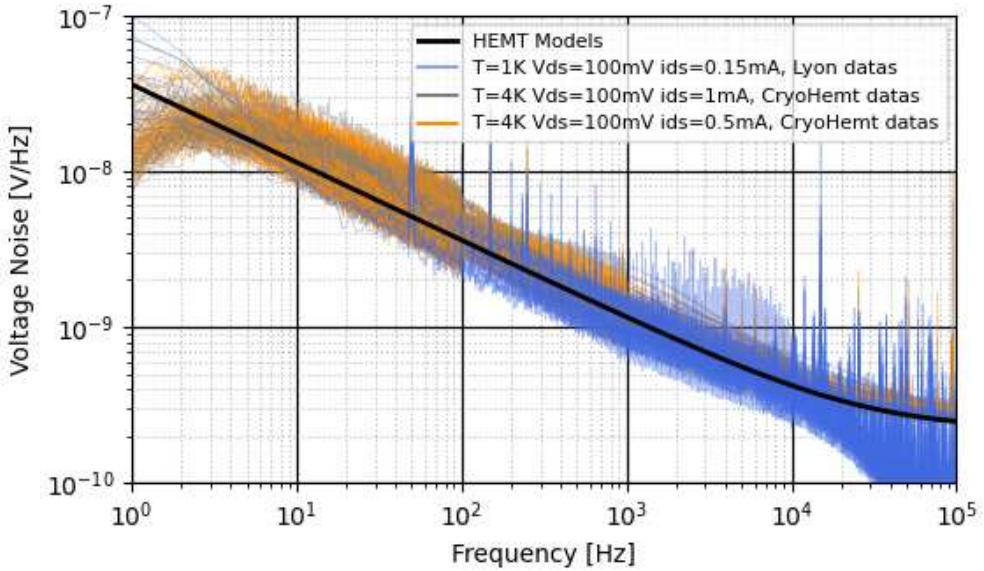


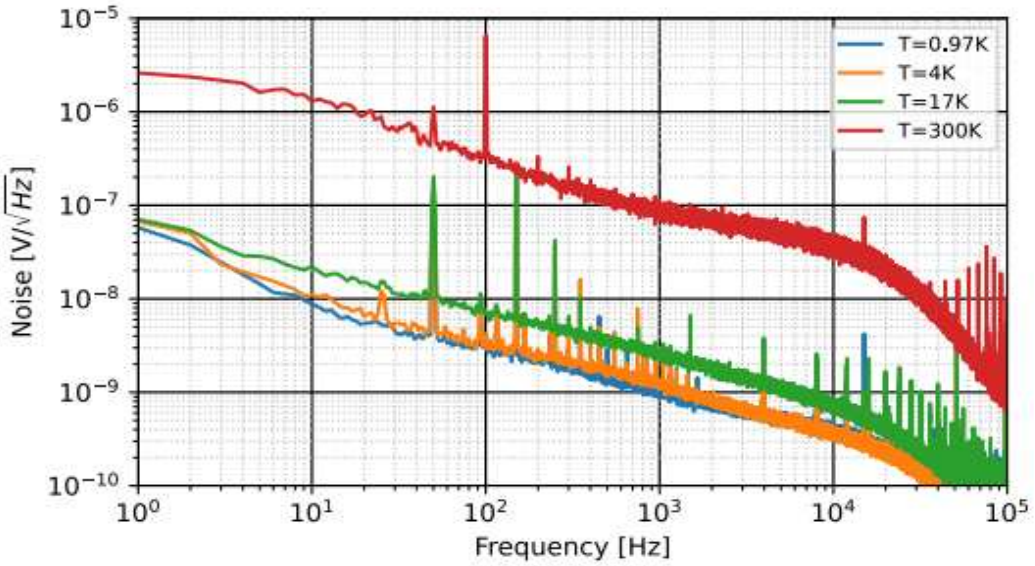
- Dilution cryostat for R&D, temperature of ~13mK
- Measurement of 4 detectors with EDELWEISS electronics
- Two stages for HEMTs:

  - Stage 1K characterisation

  - Cold finger detector measurement

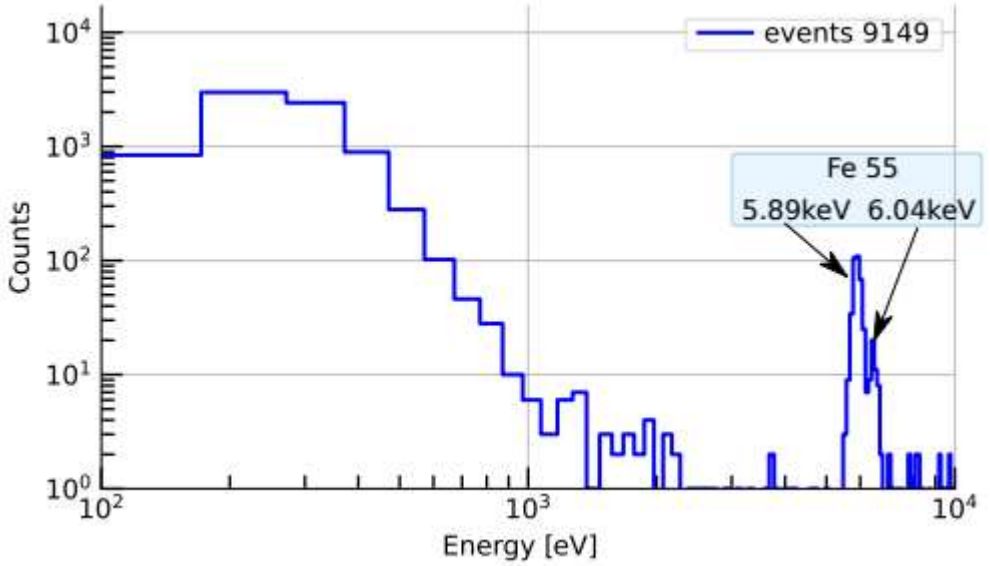
Voltage noise study





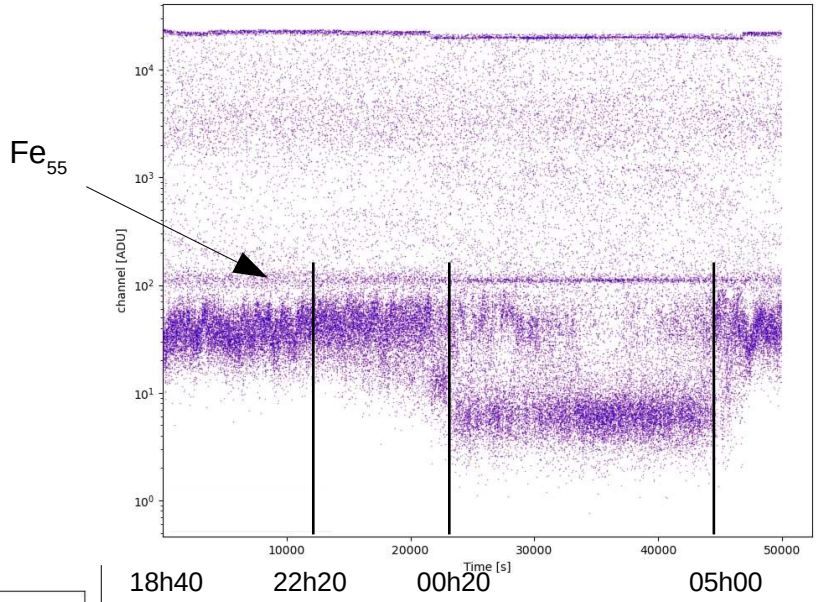
- Characterisation of the bias points of the detectors (possibility to work with less dissipated power)
- Bias point and voltage noise study of 30 HEMTs
- Work at different temperatures, possibility to place HEMTs at 1K
- Constraining the final electronics (temperature, dynamics, ...)

Heat channel with HEMT

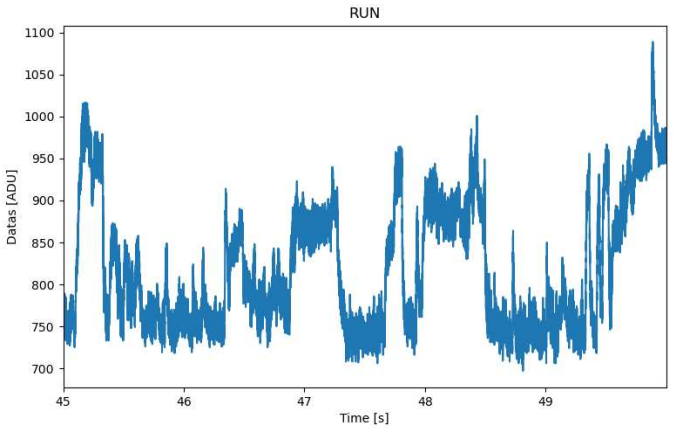


- Measurement with dead resistance corresponds to the model
- Measurement on RED21 (**17eV** with **FET** electronic)
- Best heat energy resolution with HEMT = **98eV**

Excess noise



- Environmental noise, disappears at night
- Different set-up detectors/ cabling → same noise
- Starts between 00:00 and 05:00
- FET insensitive to noise

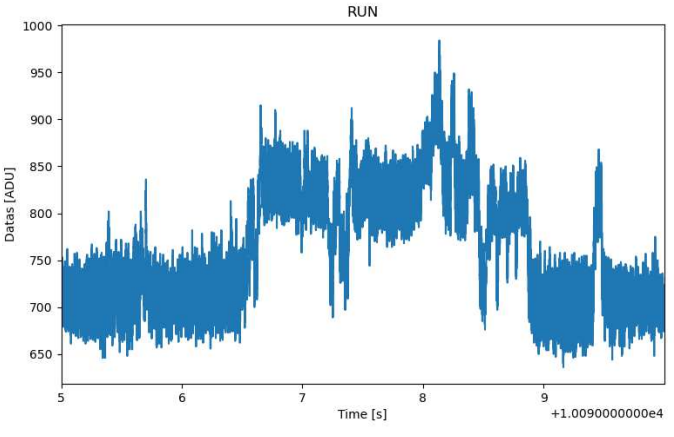


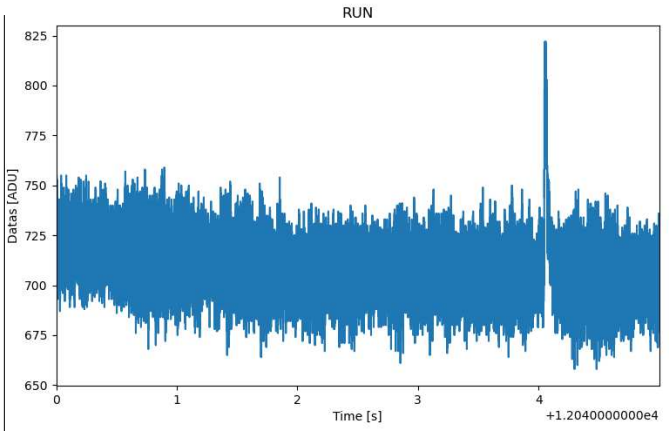
Very noisy period:

- 18h40-22h20 and 5h00-6h00
- Appears every seconds

Noisy period:

- 22h20-00h20
- Appears every 5 seconds



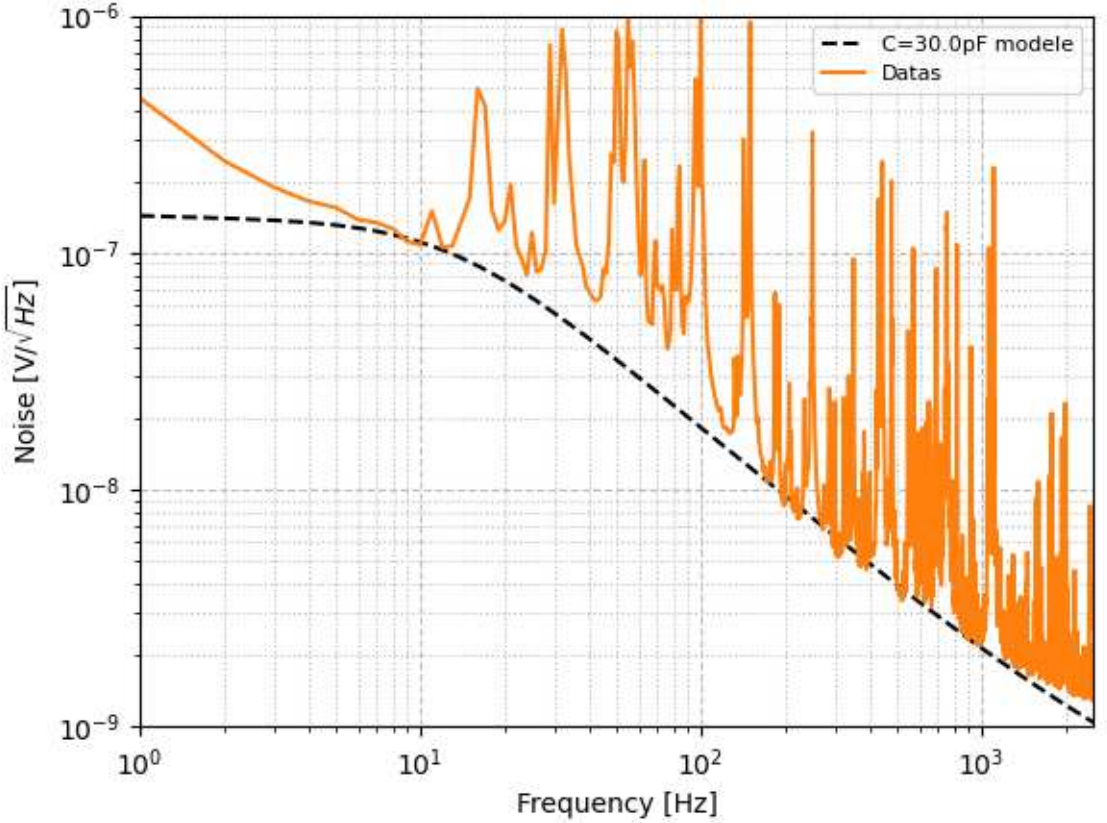


Quiet period:

-00h20-5h00

-The structure does not emerge from the white noise

Ionisation channel with Hemt



- Cabling capacitance + detector capacitance of ~ **30 pF**
- Model resolution 70 eV_{ee}, best resolution **160 eV_{ee}**
- Factor two to be gained to fit the model

Outlook

- Model: 10 eV heat channel with HEMT or FET, 20 eVee ionisation channel with HEMT
- Heat channel detector:
  - Understanding excess noise
  - Possible use of FETs to obtain 10eV (more technically complicated)
- Ionisation channel:
  - Better results with HEMT than FET electronics
  - Factor two to be gained
- First detectors for Ricochet end 2022