Reinforcement learning for signal processing of low temperature thermal detectors for a direct neutrino mass measurement

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Outlines

- Neutrino mass measurements
- Calorimetric approach
- The HOLMES experiment
- Data analysis
- Reinforcement learning technique

Neutrino mass: state of the art

- Neutrino mass measurement is a challenge
- Knowing its value has far-reaching implication
- Model independent methods: energy and momentum conservation
- Study of the beta decay or EC

Spectrometric analysis
Source: tritium ^{3}H
Leading experiments: **KATRIN** and **Project8**

Calorimetric approach
Source: holmium ^{163}Ho
Leading experiments: **HOLMES** and **ECHo**

EC and calorimetric measurement

- EC: $e^- + p \rightarrow n + \nu_e$ + inner bremmstrahlung + X rays or auger electrons
- At first order, ^{163}Ho decay:

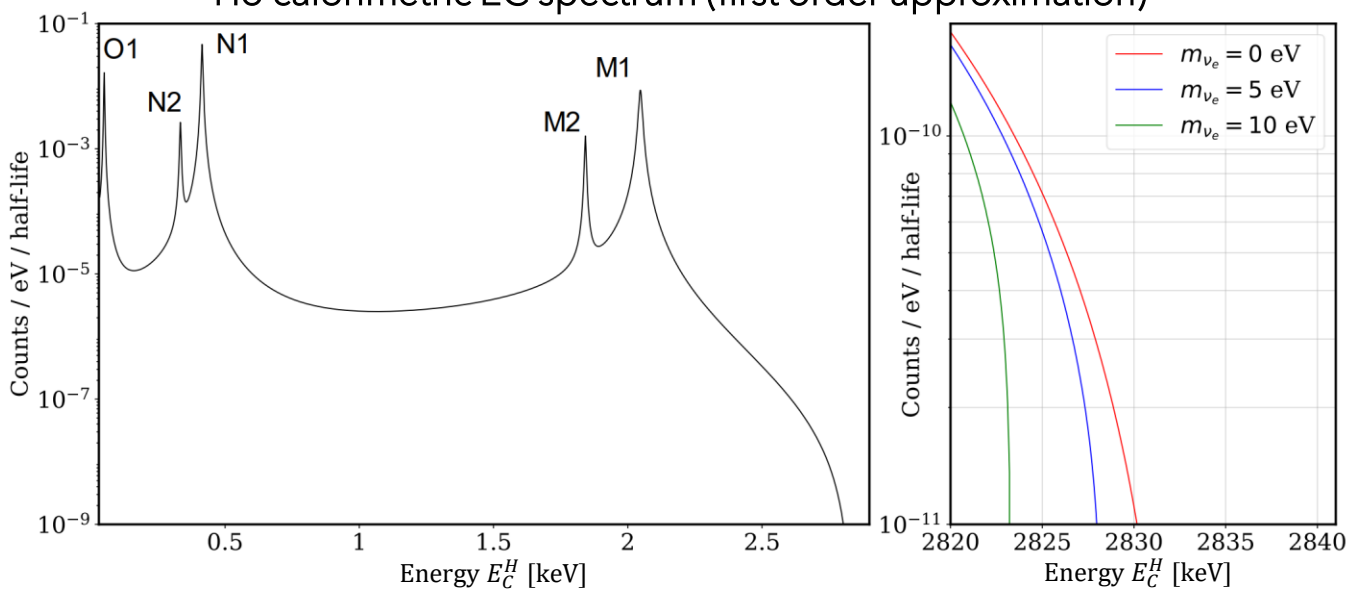
nuclear recoil + inner bremmstrahlung + X rays or auger electrons

$$^{163}Ho + e^- \rightarrow {}^{163}Dy^H + \nu_e \rightarrow {}^{163}Dy + E_C^H + \nu_e$$

- Source embedded <u>inside the detector</u>
- Measurement of all the energy except for that of the neutrino
- Study of the spectrum <u>end-point</u>:

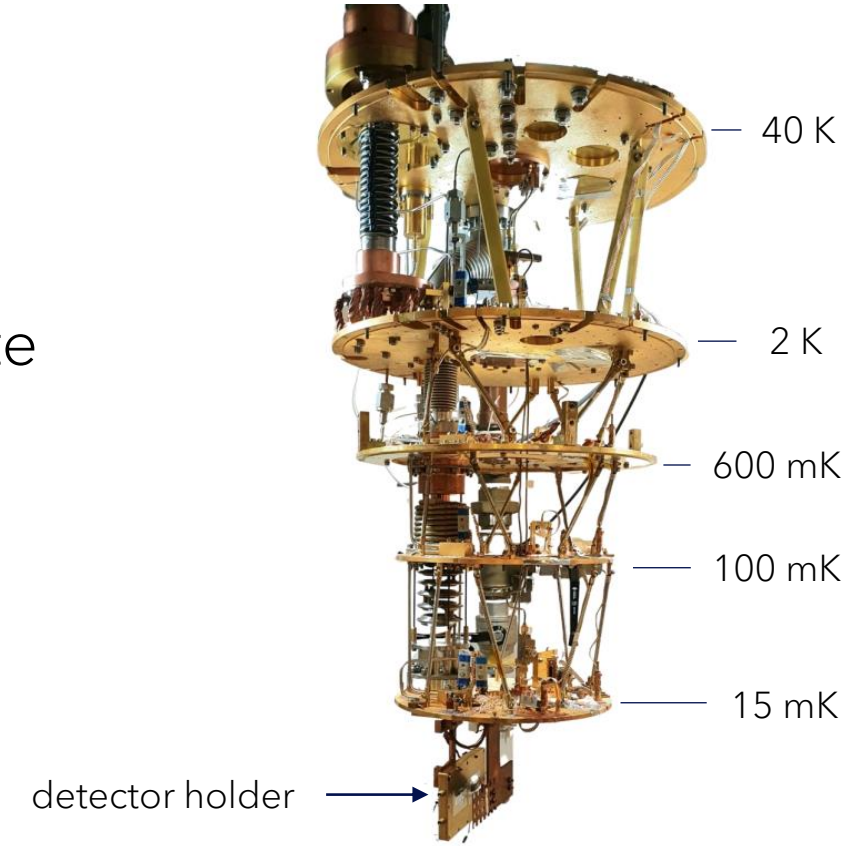
$$dN_{E_C}/dE_C \propto (\mathrm{Q} - \mathrm{E_C}) \times \sqrt{(\mathrm{Q} - \mathrm{E_C})^2 - \mathrm{m_\nu^2}}$$

Ho calorimetric EC spectrum (first order approximation)



The HOLMES experiment

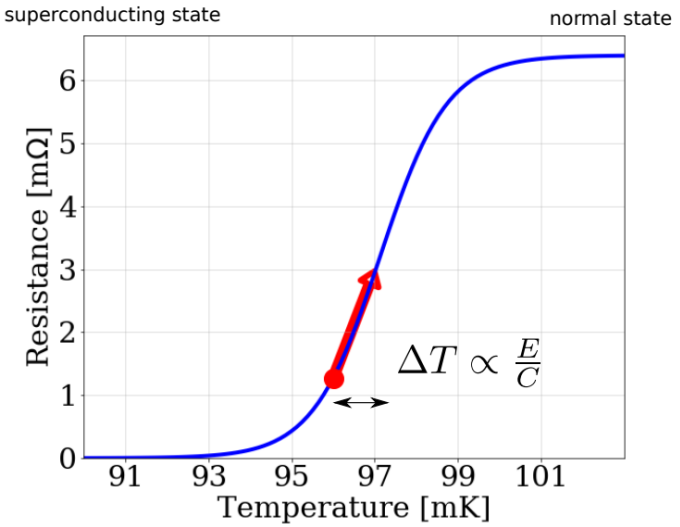
- Carried out at the University of Milano-Bicocca
- Objective: directly measure the electron neutrino mass from the EC of ^{163}Ho with a calorimetric approach
- Project's baseline setup: sensitivity on the neutrino mass of around 2 eV
- How? 1000 detectors, each with 300 Hz of activity rate and with 3 years of data-taking
- Low Temperature Detectors: TESs

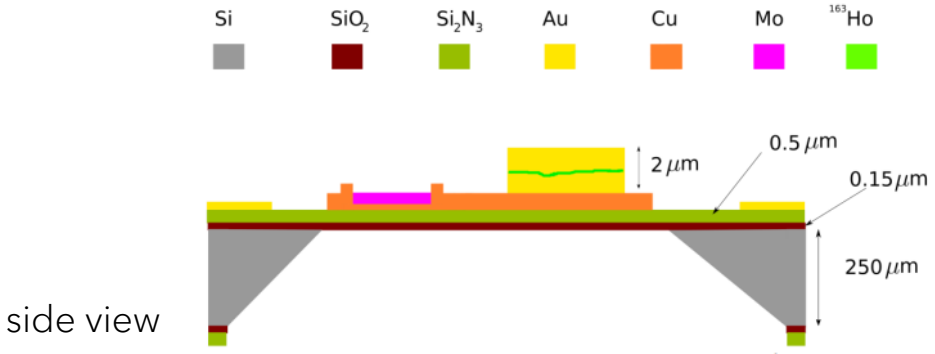


HOLMES detectors

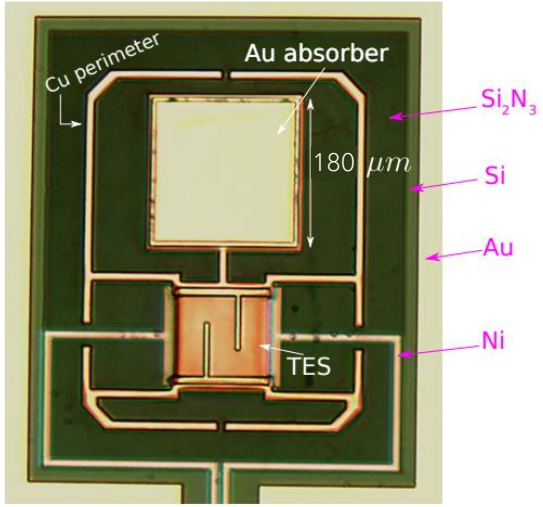
- Sensitive thermometers made of superconductive film
- The resistance is strongly dependent on temperature
- Mo/Cu bilayer film
- $T_C \sim 100\ \mathrm{mK}$
- Detector design: TES + Au absorber + ^{163}Ho source
- Microwave multiplexing readout

Transition shape of an Holmes TES





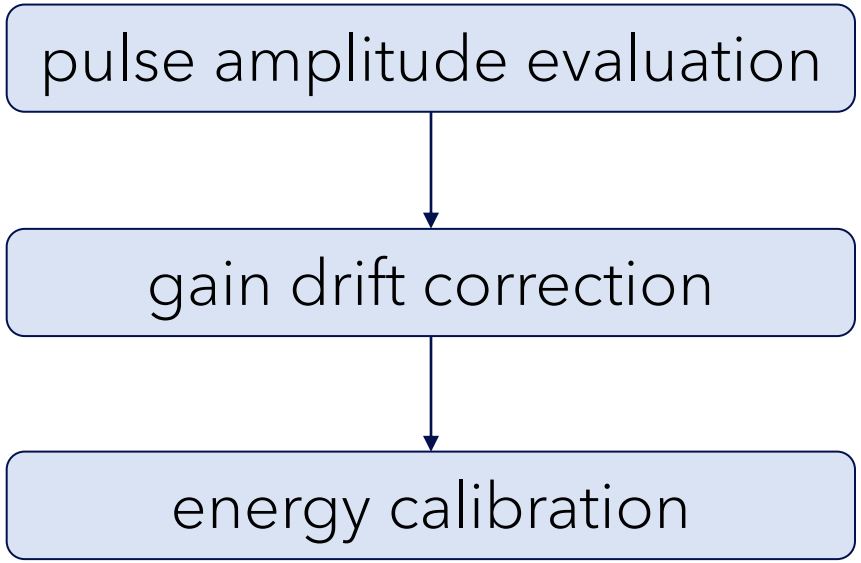
side view

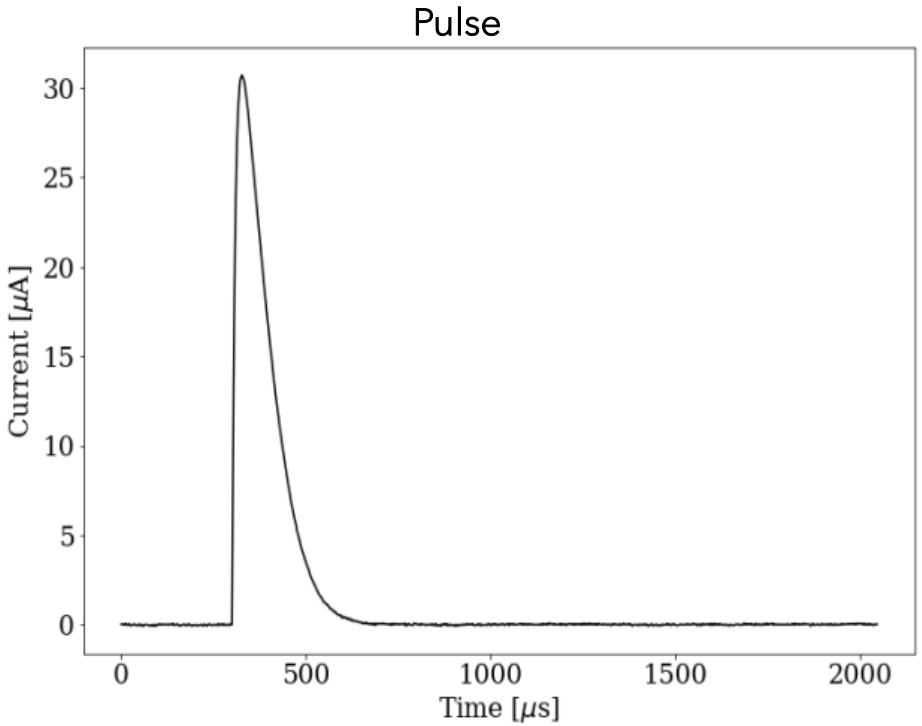


top view

Data analysis

- Convert raw measured data into calibrated one
- Pulse energy:



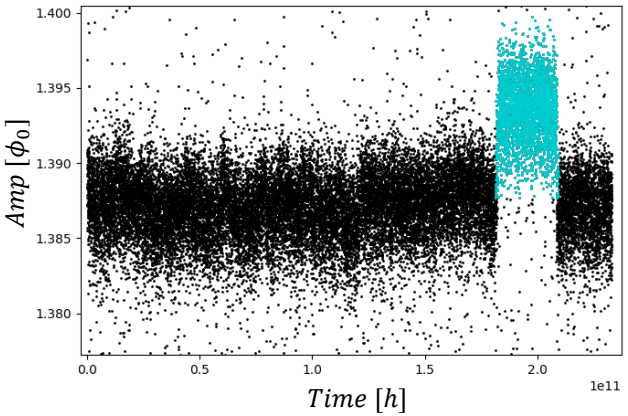


- Python algorithms with reinforcement learning technique

Gain drift correction

- Due to oscillations in bath temperature
- Amplitude of signals, caused by monochromatic energy deposition, changes over time
- Distortions appear in the final spectrum
- Select events in a monoenergetic peak and perform a linear regression fit

1



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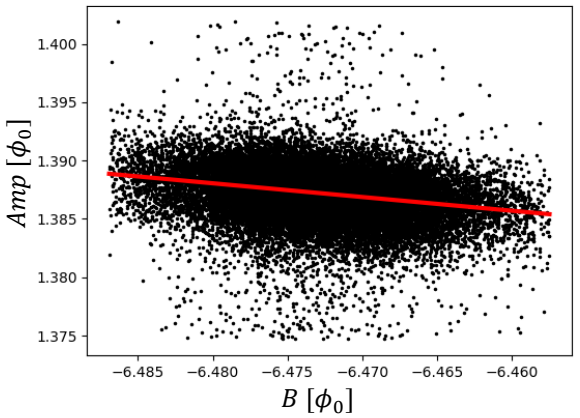

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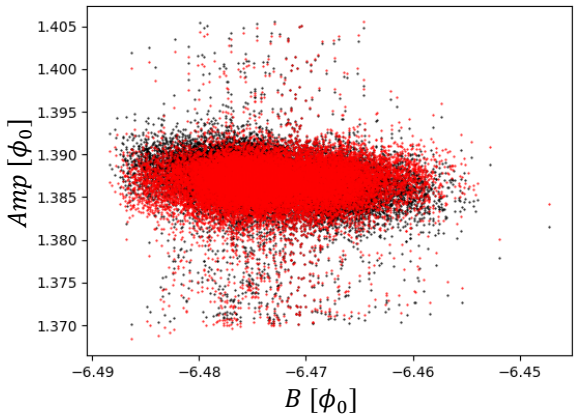

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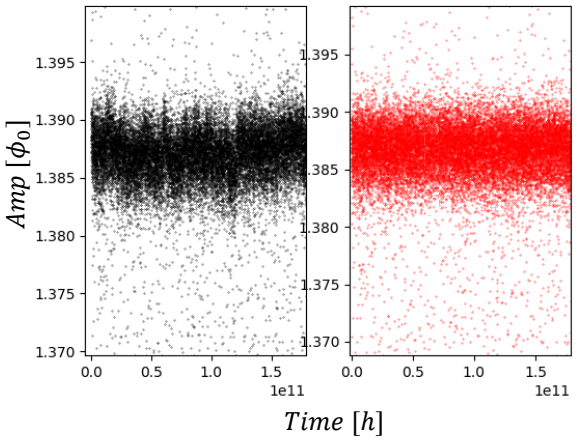
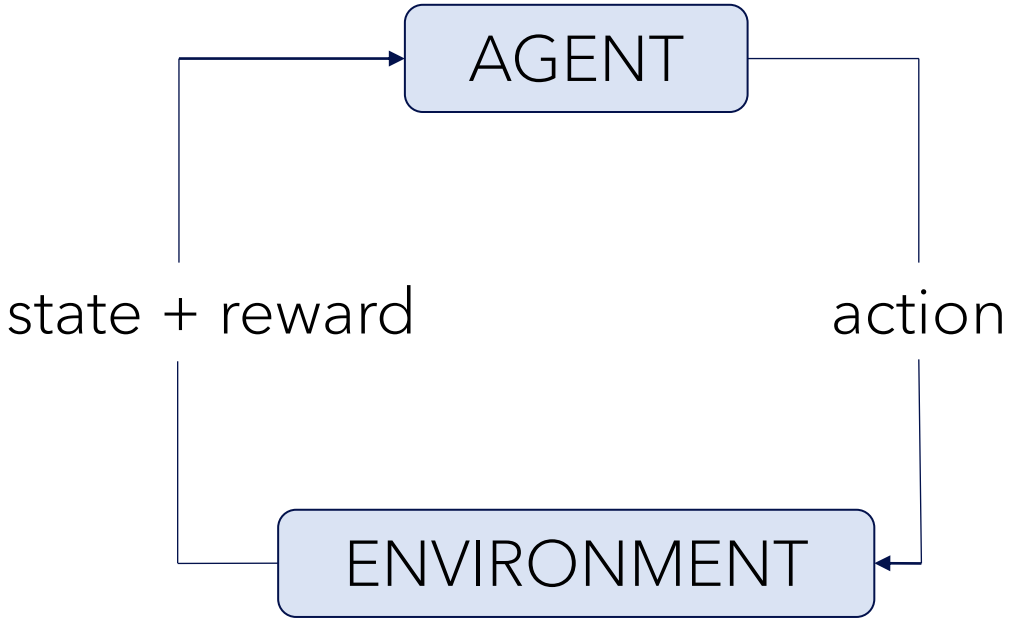


Reinforcement learning technique

- Teach a machine to make decisions and take actions in an automated way
- Agent's objective: define a policy
- Learn from experience



Conclusion

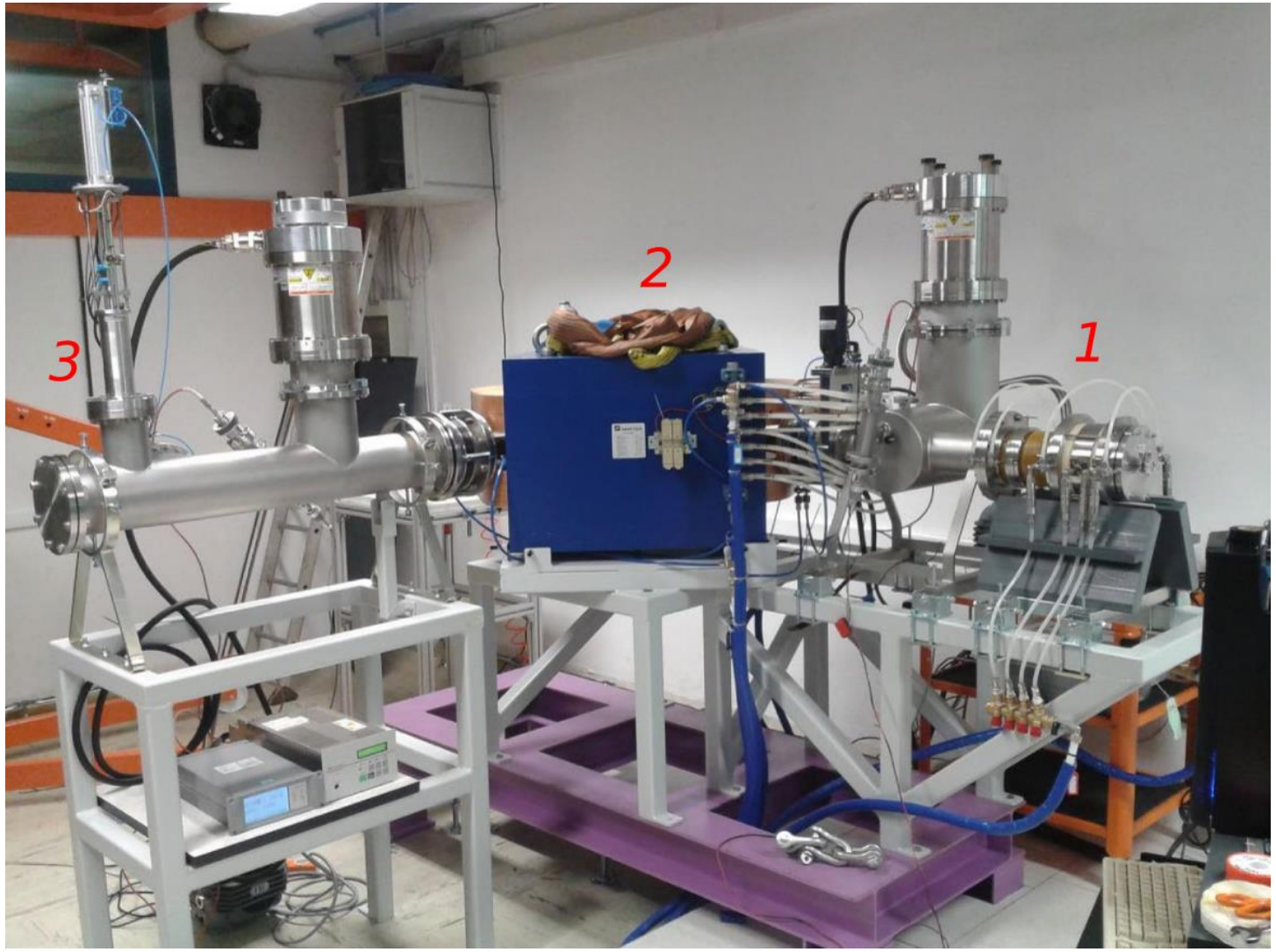
The implementation of automated algorithms could have significant implications in the data analysis software:

- Speed up the data analysis
- Advantages in streamlining the analysis process
- For multichannel experiments with low temperature detectors
- Future developments in others analysis steps

Thank you for your attention

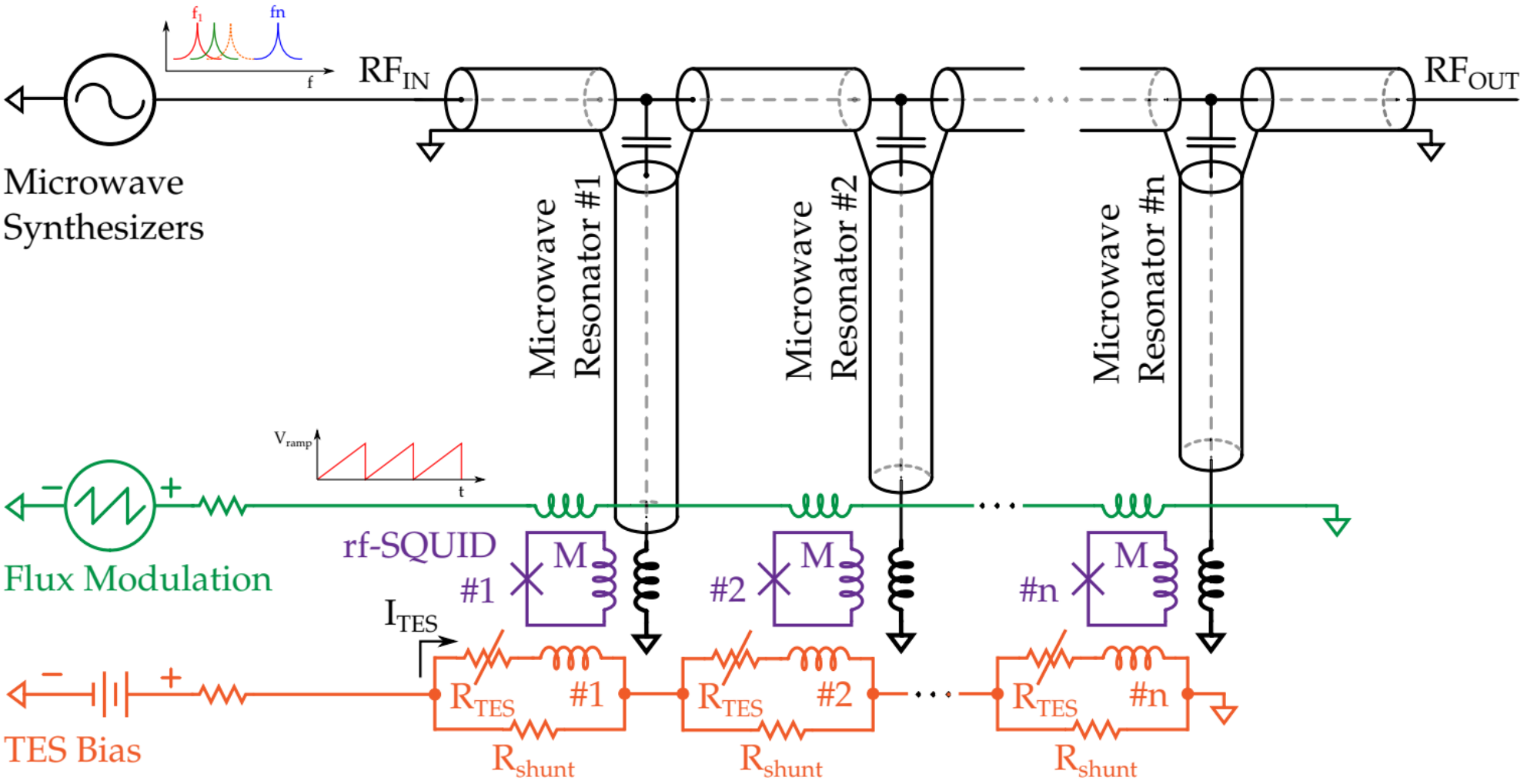
Backup

Source embedding

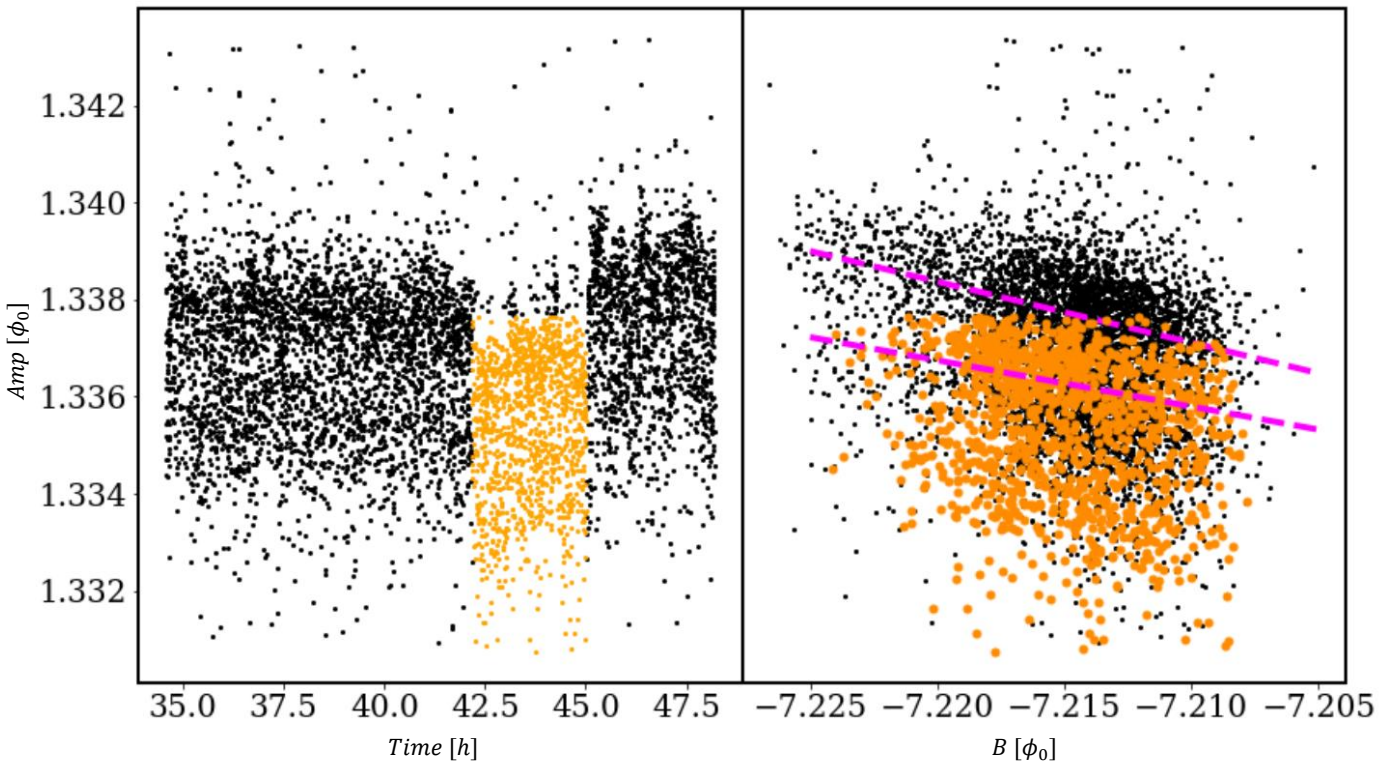


1. The sputter target and the acceleration section
2. The magnetic dipole mass analyser
3. Detector chip

Microwave multiplexing readout



Gain drift correction 1



Gain drift correction 2