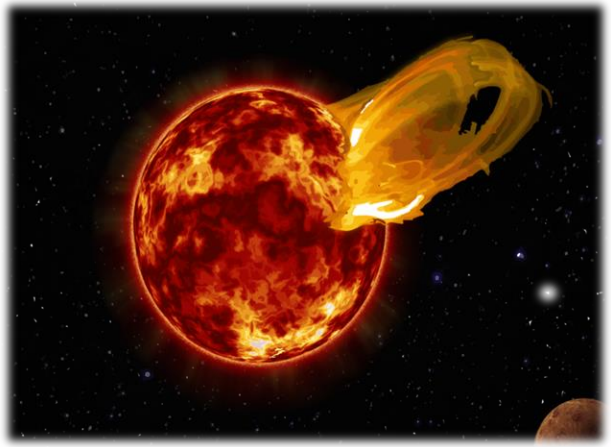
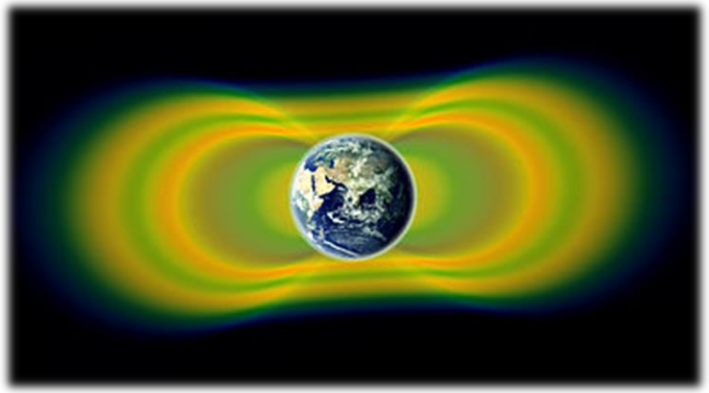
ESCCON

09/03/2021

Creation of a database for single events latch-up detection on Atmel SAM3X microcontroller





PhD student : Adrien Dorise
Thesis supervisors : Louise Travé-Massuyès
Corinne Alonso
Audine Subias
François Vacher
Leny Baczkowsky
Thomas Torloting

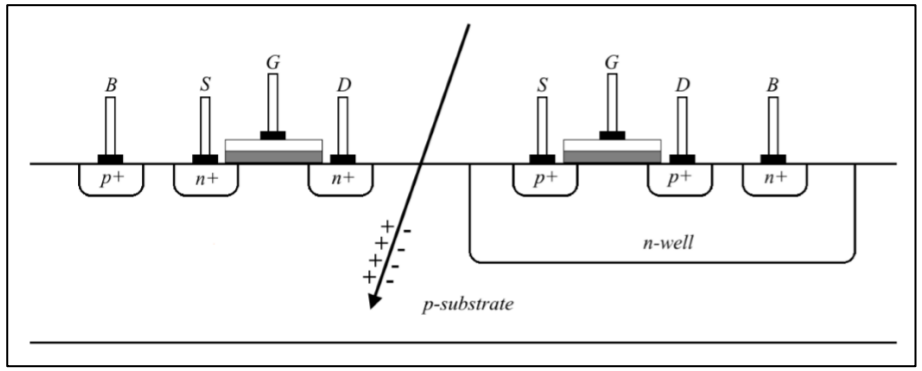
Grant by CNES – région Occitanie

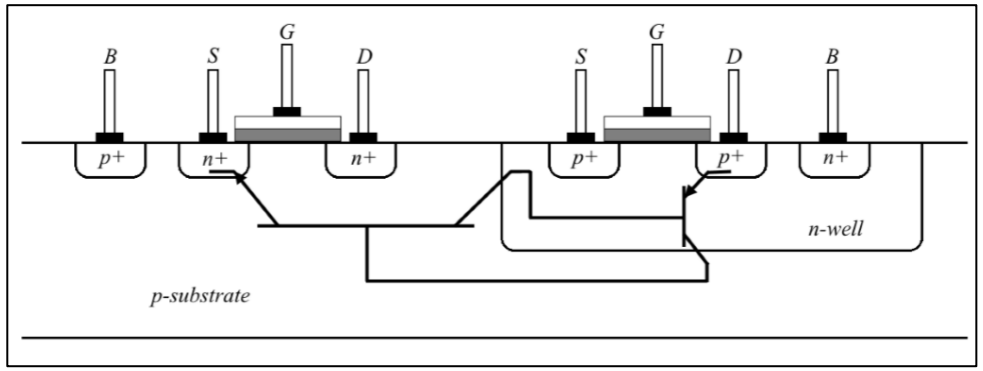
Context

Single Event Effects (SEE)

- Context
- Data sets
- Features
- Electronic board
- Anomaly detection

> SEEs in a micro-electronic device are caused by a single energetic particle and can take many forms.
  - Single Event Upset (SEU) is a logical change of state by one ionizing particle striking a sensitive node.
  - Single Event Latch up (SEL): Consumption current modification due to the creation of a low-impedence path triggering a parasitic structure, possibly leading to the destruction of the component. A power cycle is required to correct the situation.





Ionizing particle hitting the semi-conductor

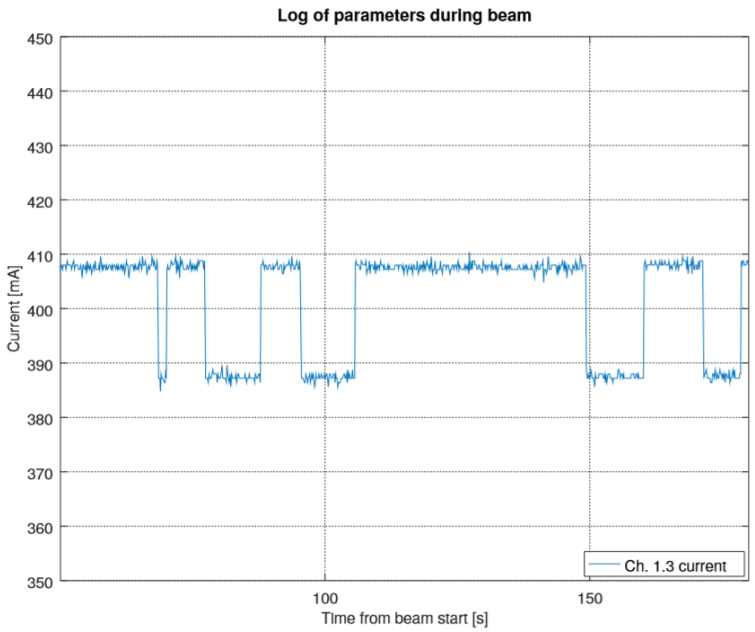
Source: Jonas Bikerland Carlsen, 2018

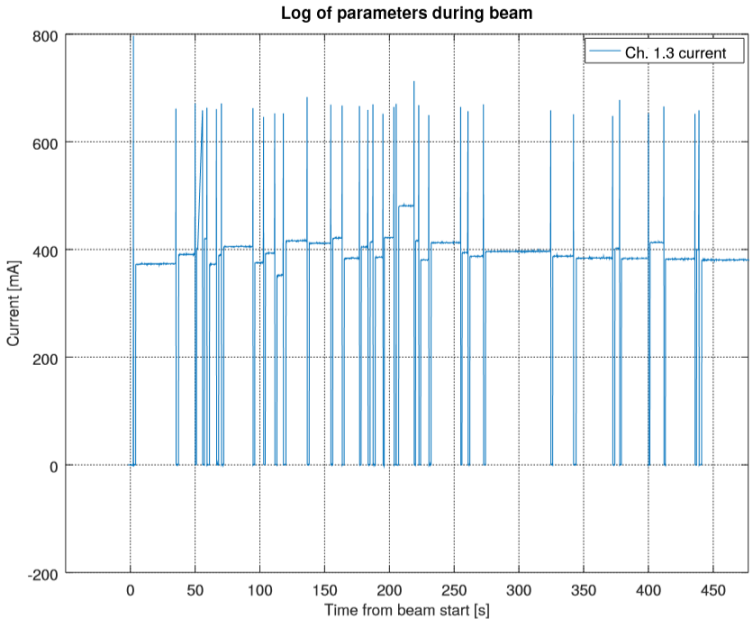
Context

Single Event Effects (SEE)

- Context
- Data sets
- Features
- Electronic board
- Anomaly detection

> µLatch-up: Non destructive latch up
  - Consequence => High Current Event (HCE)
  - Can be hard to detect because lost in the original signal.
  - Persistent without a power reset.





Radiation testings on Raspberry pi 3

Source: Jonas Bikerland Carlsen, 2018

Context

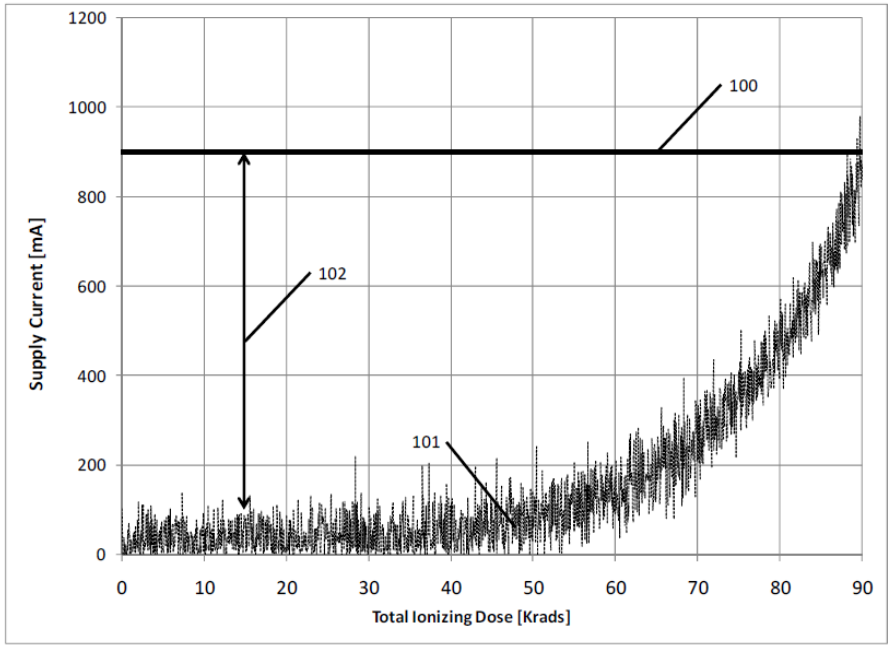
Today's solutions

- Context
- Data sets
- Features
- Electronic board
- Anomaly detection

- Shielding (protect against radiation dose)
- Hardening

} Expensive

- Anti latch-up system



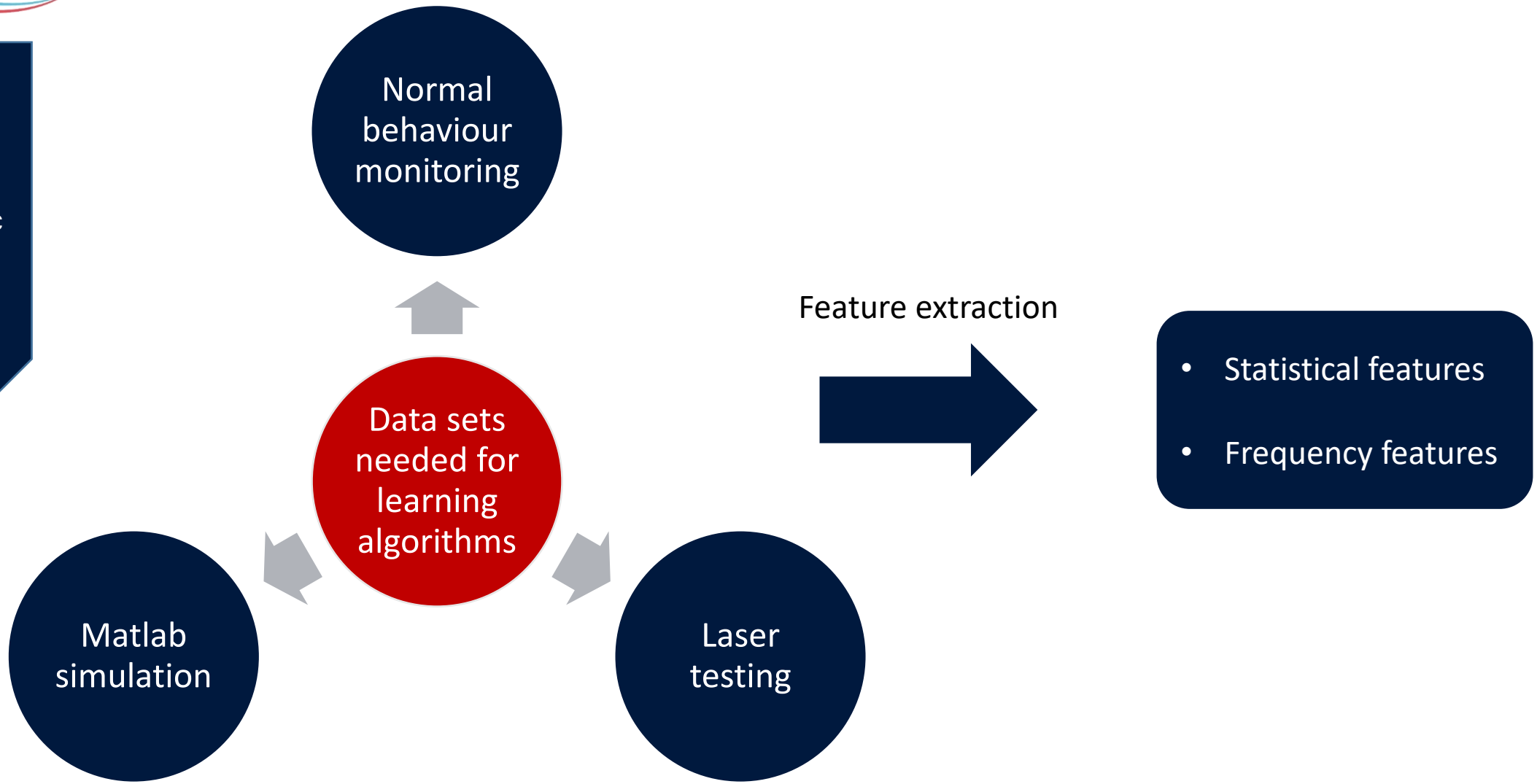
Anti latch-up system example

Impossible to detect µLatch-up

Source: INVAP/Roberto Manuel CIBILS, 2019

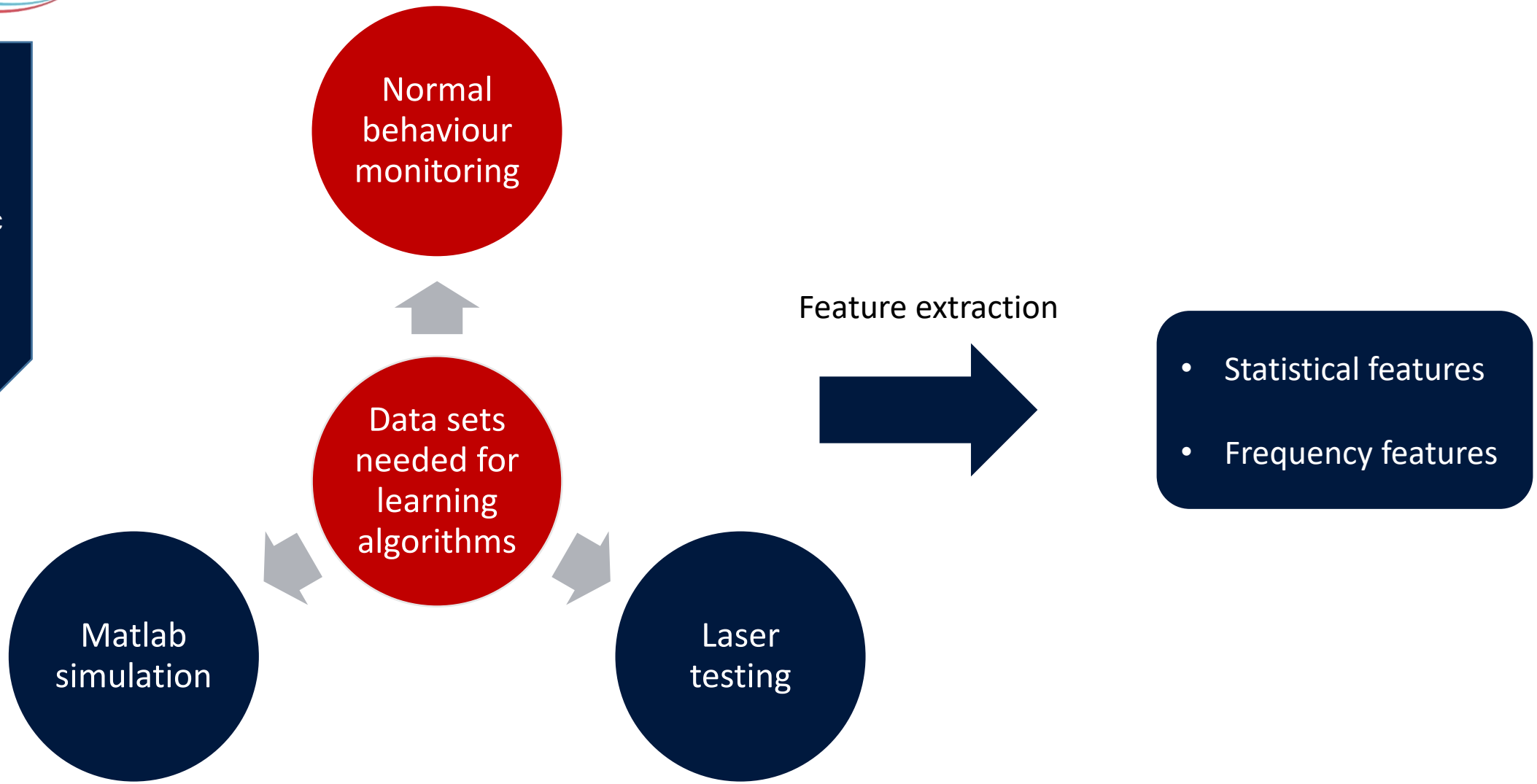
Data Sets

- Context
- Data sets
- Features
- Electronic board
- Anomaly detection



Data Sets

- Context
- Data sets
- Features
- Electronic board
- Anomaly detection



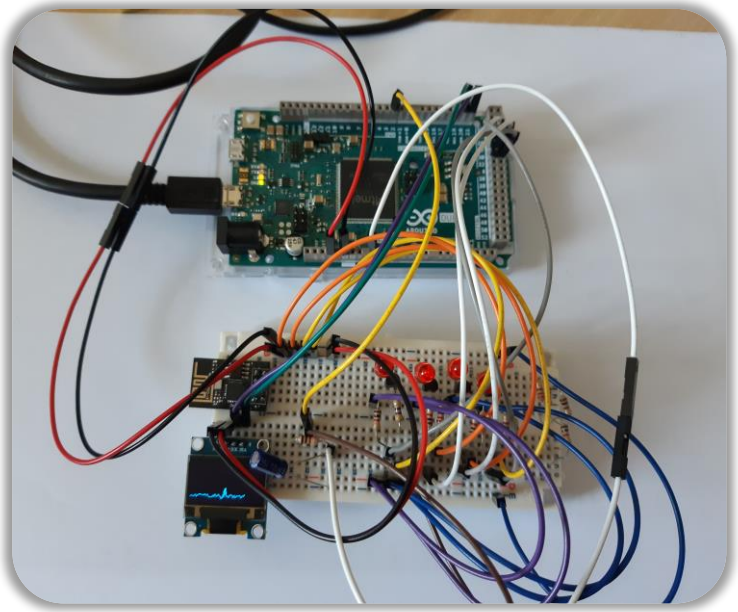
Data Sets

- Context
- Data sets
- Features
- Electronic board
- Anomaly detection

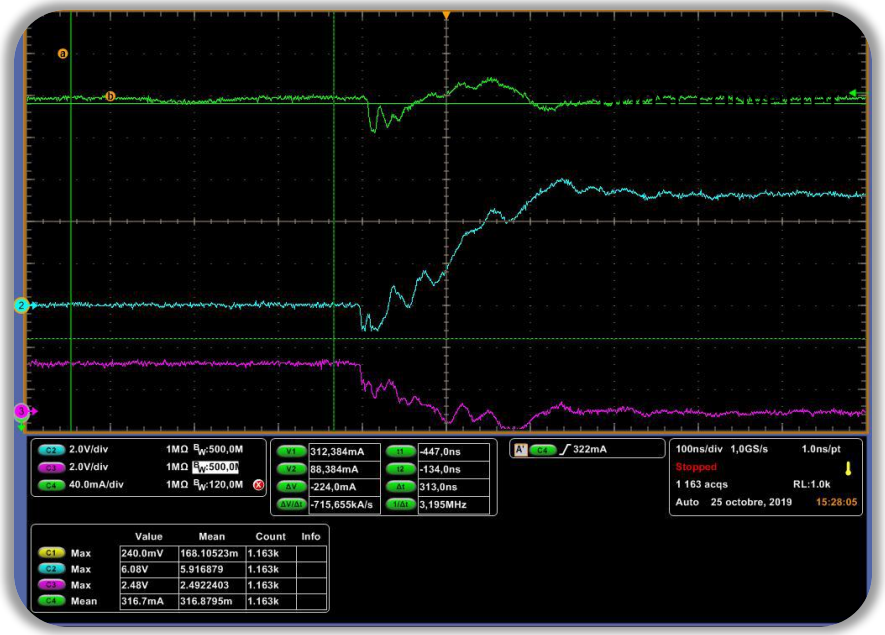
Normal behaviour monitoring

Arduino Due board equipped with a SAM3X8E microcontroller used for tests

- 32 bits Cortex-M3 core
- ARMv7-M architecture
- 84 MHz clock speed



Arduino Due



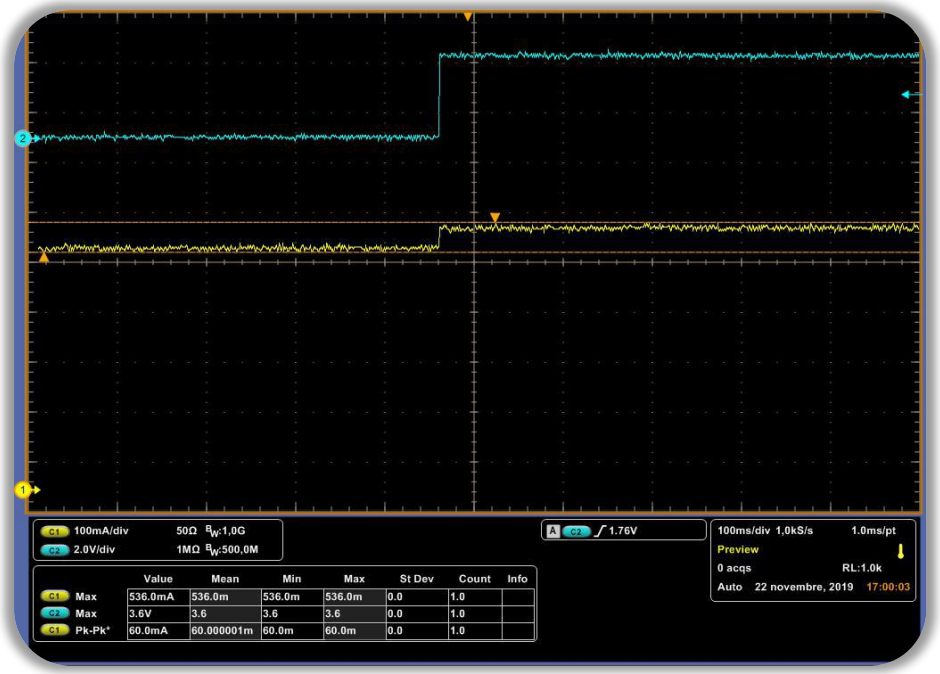
Consumption current on Boost converter

Data Sets

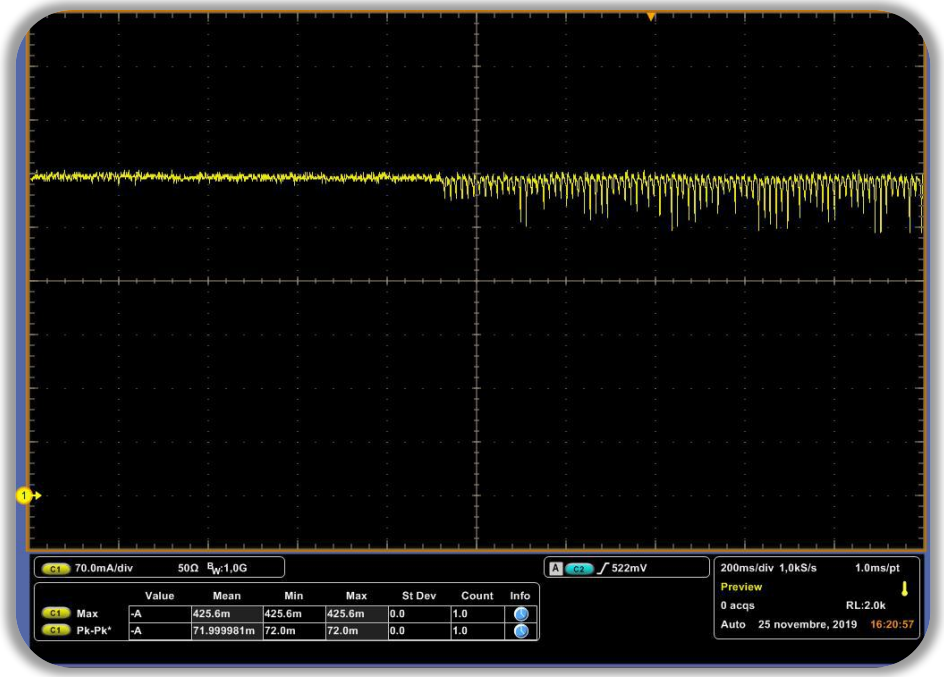
- Context
- Data sets
- Features
- Electronic board
- Anomaly detection

Normal behaviour monitoring

- 2 major consumption profiles
- Functions significantly impact consumption current of the SAM3X8E microcontroller



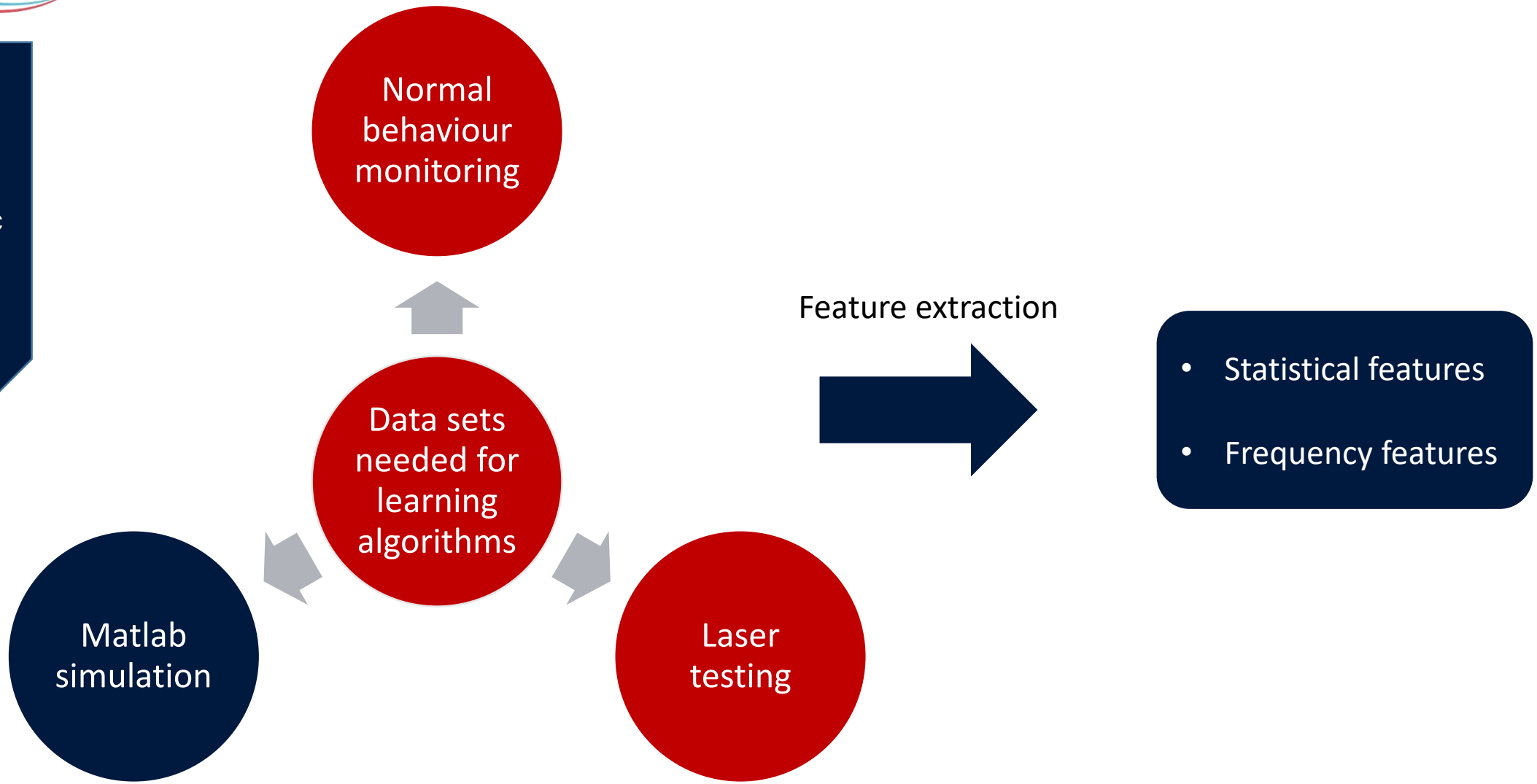
I/O consumption



Software consumption

Data Sets

- Context
- Data sets
- Features
- Electronic board
- Anomaly detection

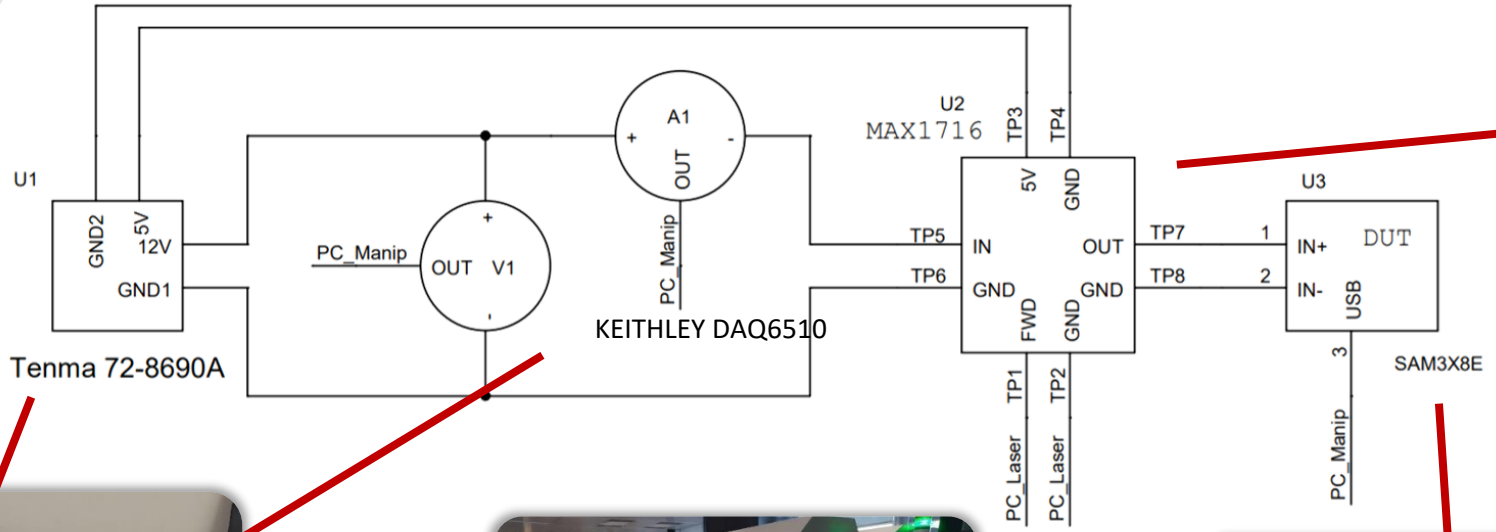


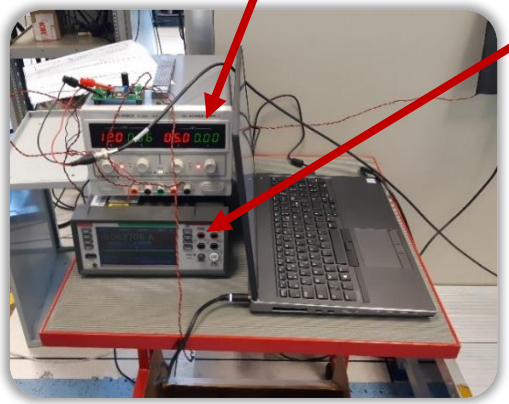
Data Sets

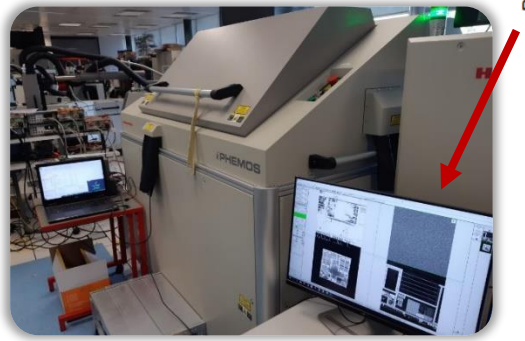
- Context
- Data sets
- Features
- Electronic board
- Anomaly detection

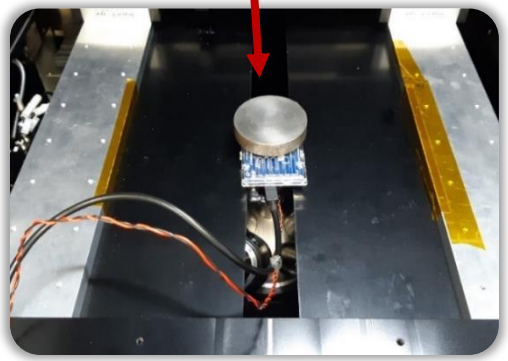
Laser testing

Max Power	Wavelength λ	Pulse repetition frequency
2500 mW	1064 nm	8 KHz







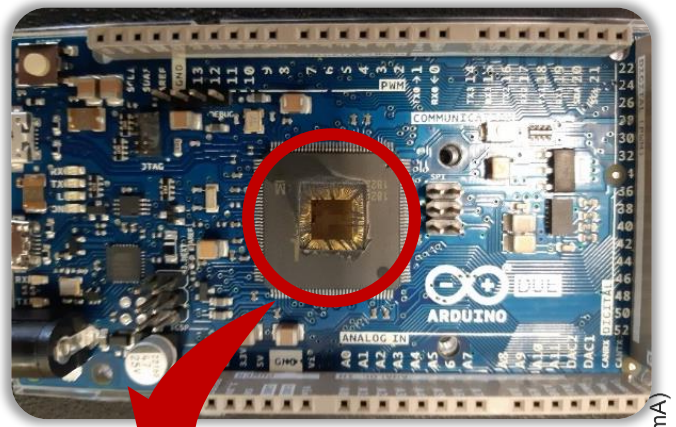


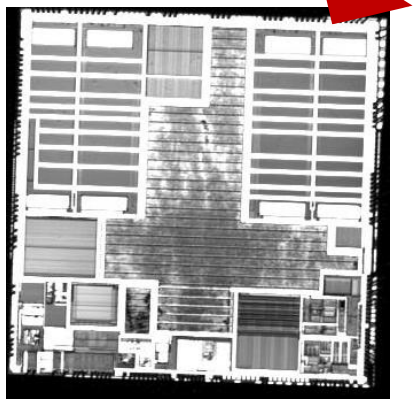
Laser bench, CNES Toulouse

Data Sets

- Context
- Data sets
- Features
- Electronic board
- Anomaly detection

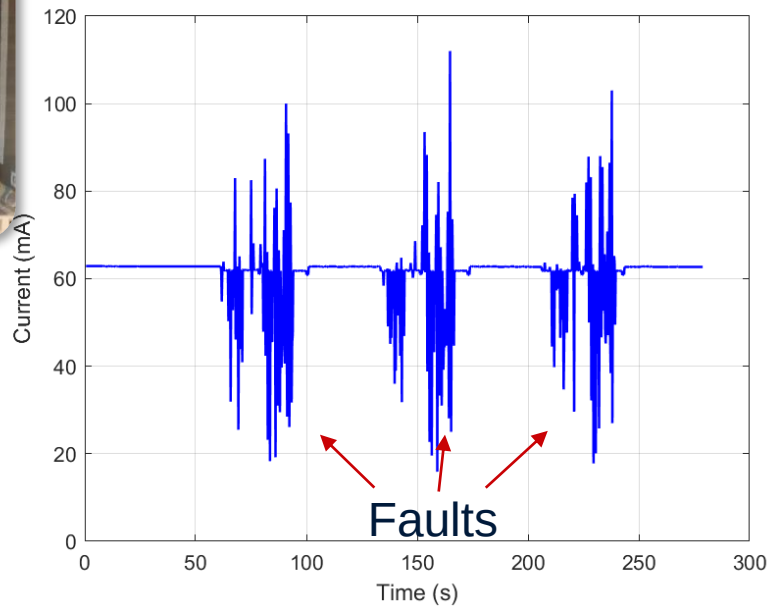
Laser testing

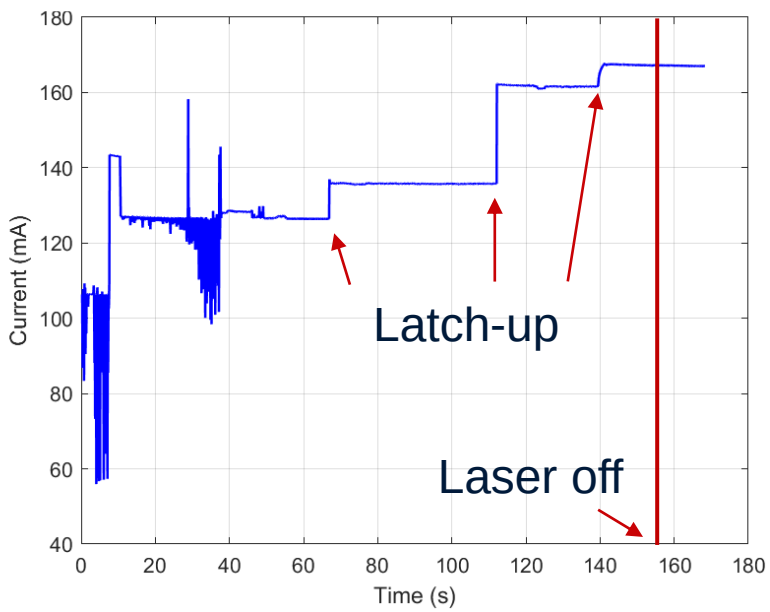




2 types of faults occurred during the laser testing

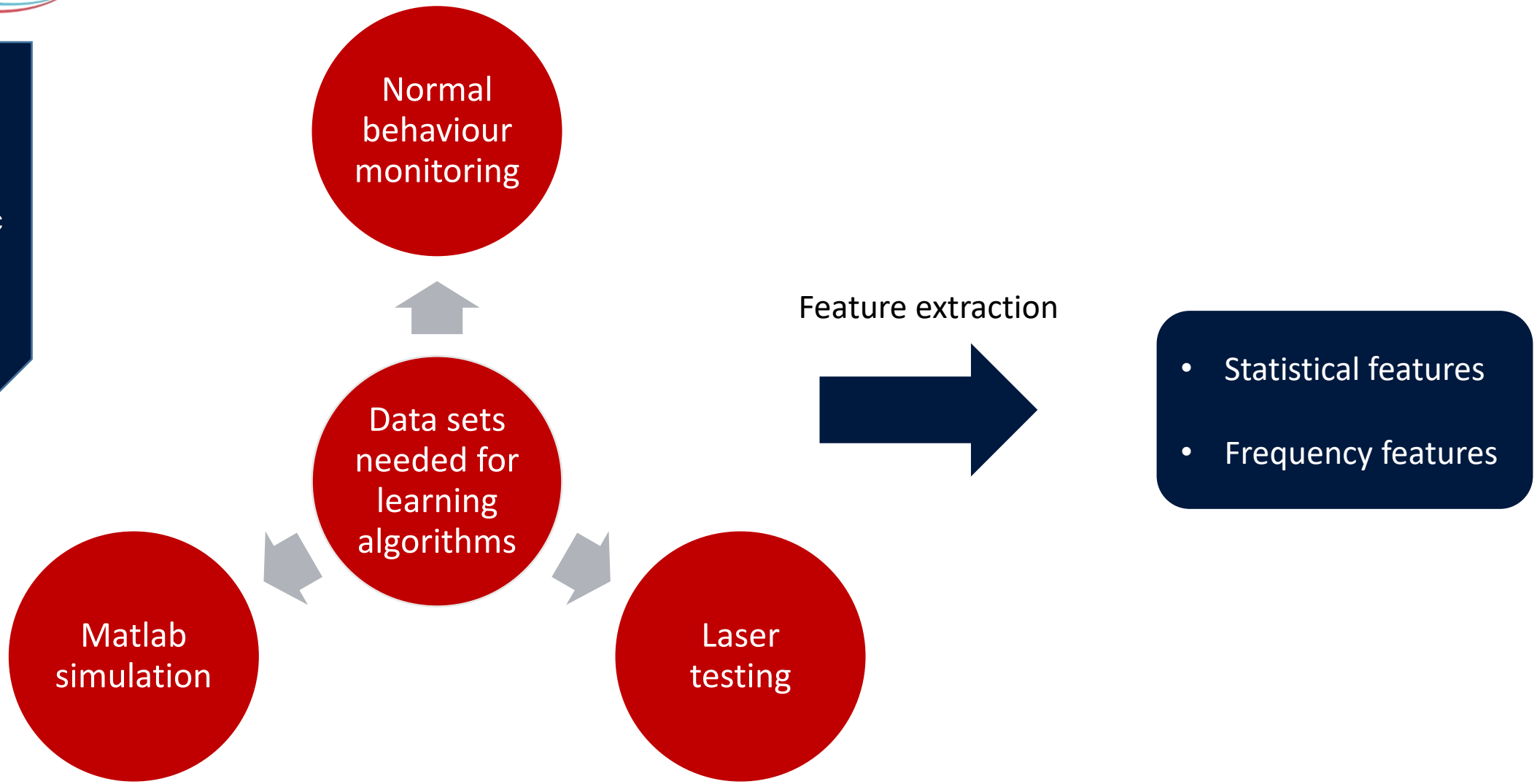
- Current faults
- Latch-up





Data Sets

- Context
- Data sets
- Features
- Electronic board
- Anomaly detection

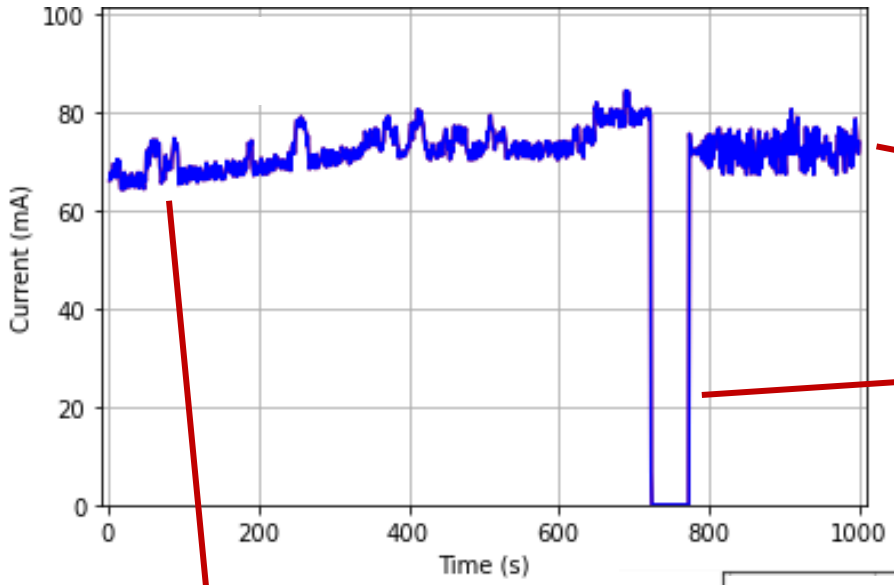


Data Sets

- Context
- Data sets
- Features
- Electronic board
- Anomaly detection

Matlab simulation

> Generates random data sets
> Not a model based generator
  - Not representative of reality
  - Mainly used to test statistical features

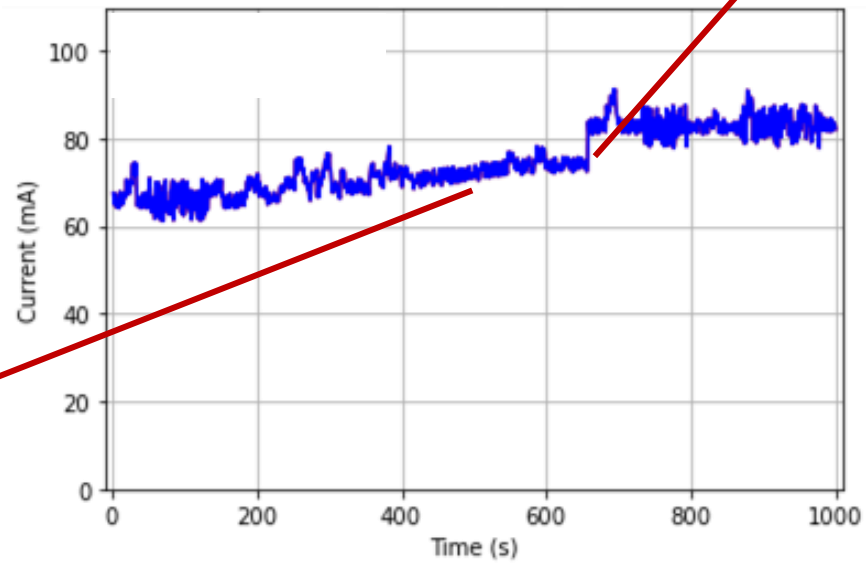


Calculation

Power cycling

I/O consumption

µLatch-up



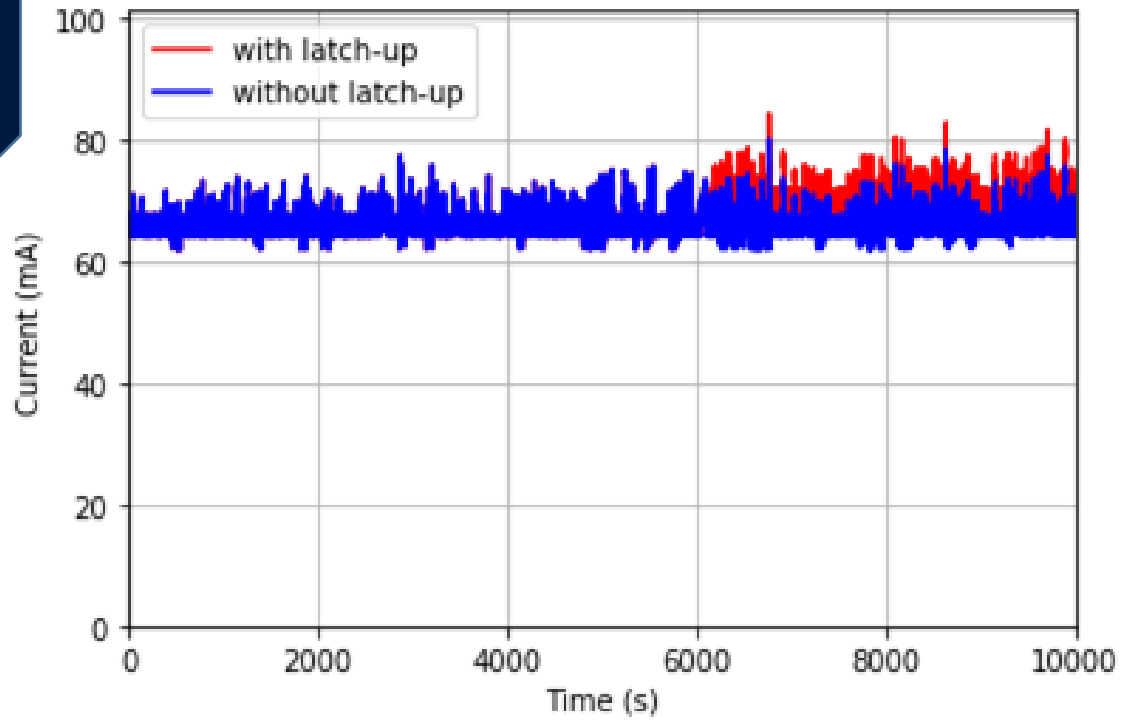
Temperature variation

Data Sets

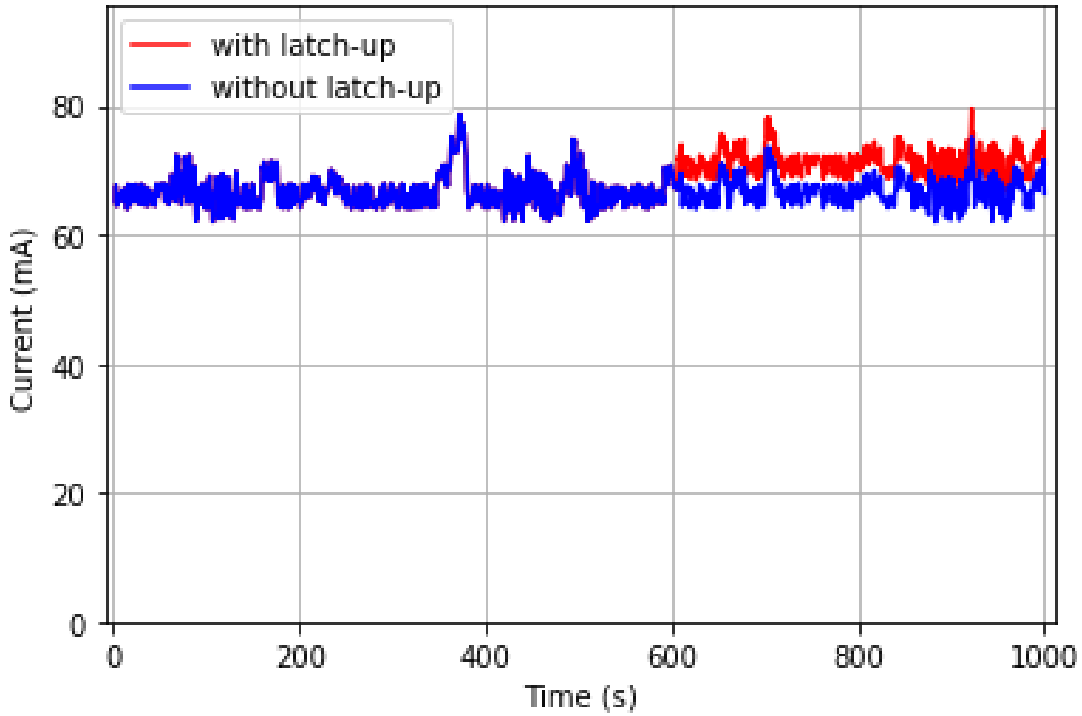
- Context
- Data sets
- Features
- Electronic board
- Anomaly detection

Matlab simulation

Training Set

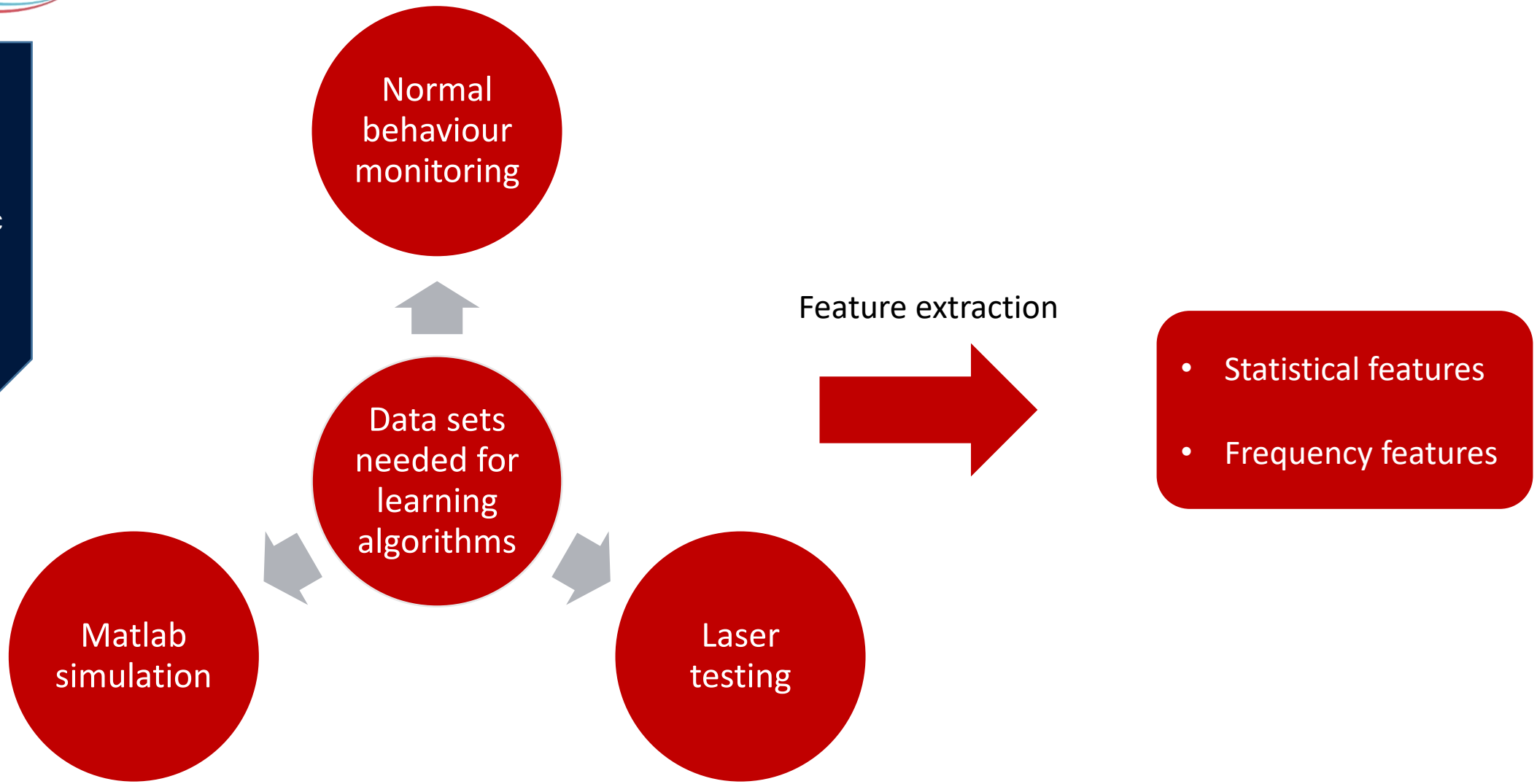


Test set



Data Sets

- Context
- Data sets
- Features
- Electronic board
- Anomaly detection



Feature extraction

- Context
- Data sets
- Features
- Electronic board
- Anomaly detection

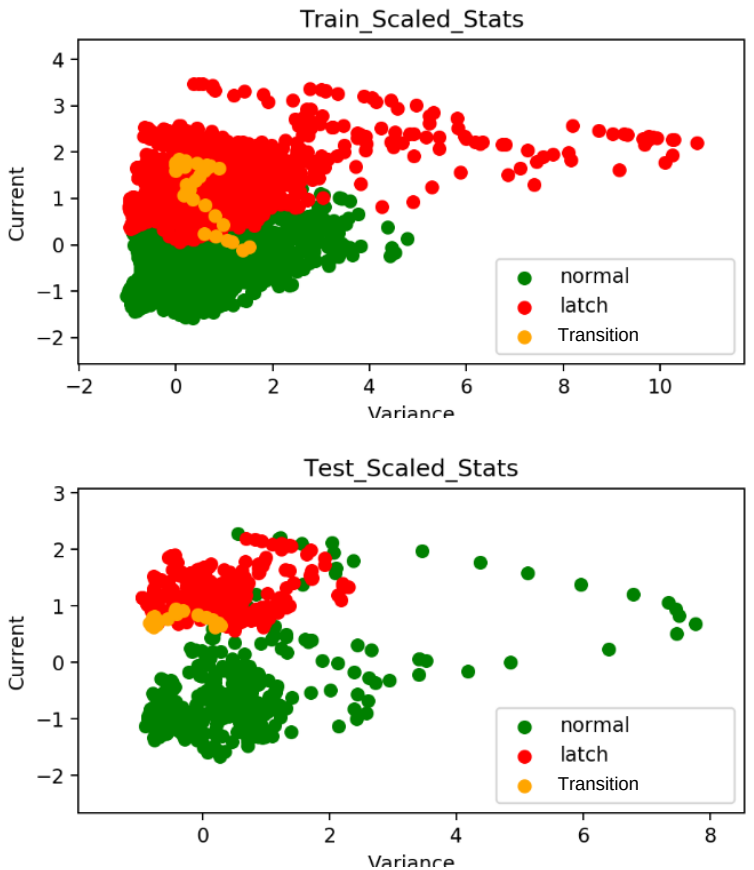
- Statistical features
- Frequency features

Statistical features used:

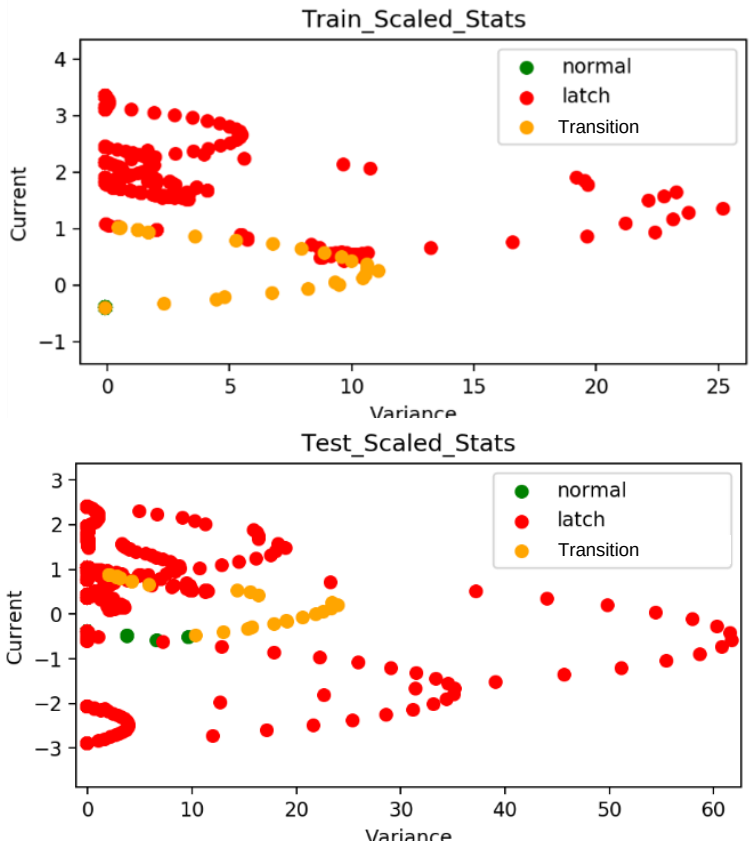
- Minimum
- Maximum
- Geometrical mean
- Variance
- Standard deviation
- Median absolute deviation
- K-statistic

Statistical features can improve detection of latch-up

Features of simulated data set



Features of real data set



Feature extraction

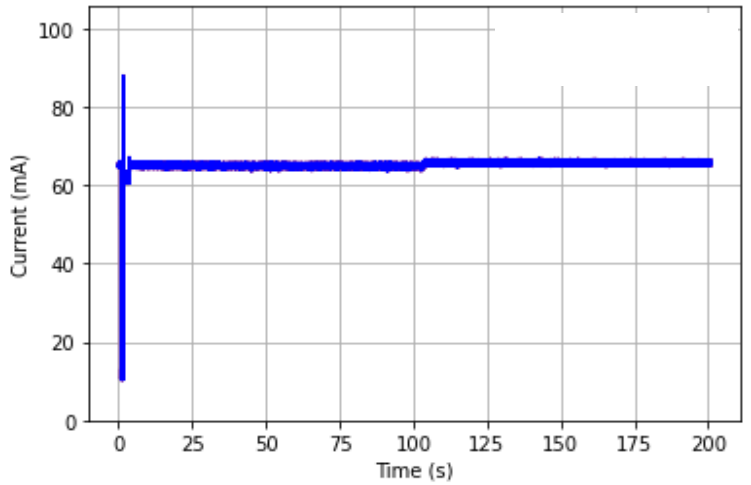
- Context
- Data sets
- Features
- Electronic board
- Anomaly detection

- Statistical features
- Frequency features

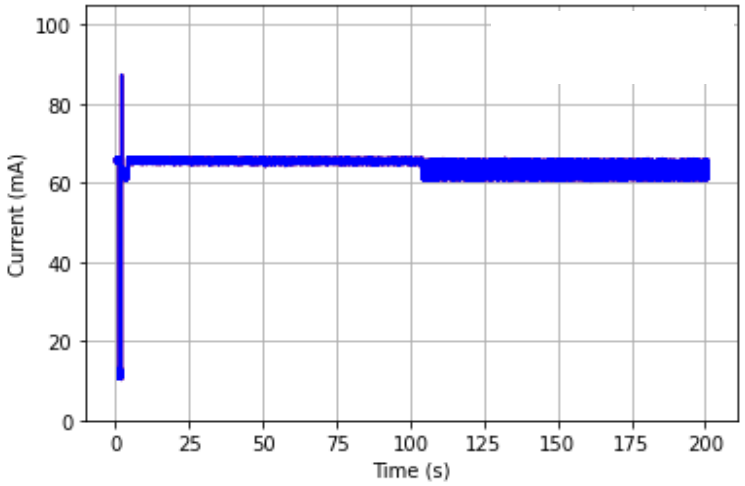
> Acquisition frequency limited to 2.5kHz

> As 0Hz frequency is dominant, we remove it from the spectrum

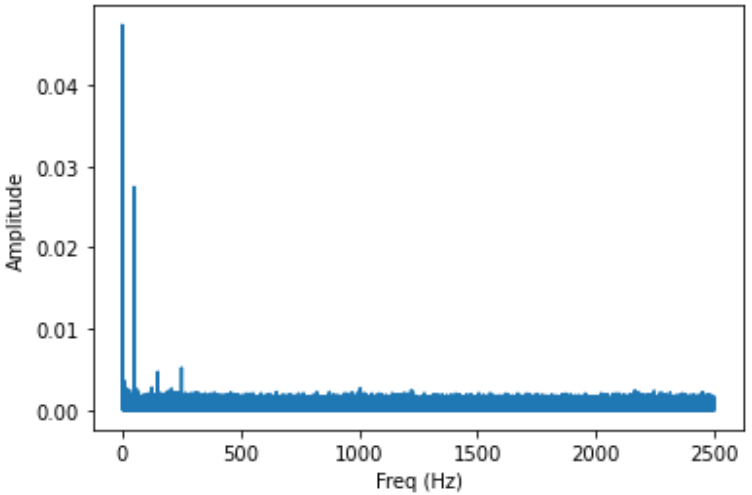
> Different Fourier spectrum depending on consumption type

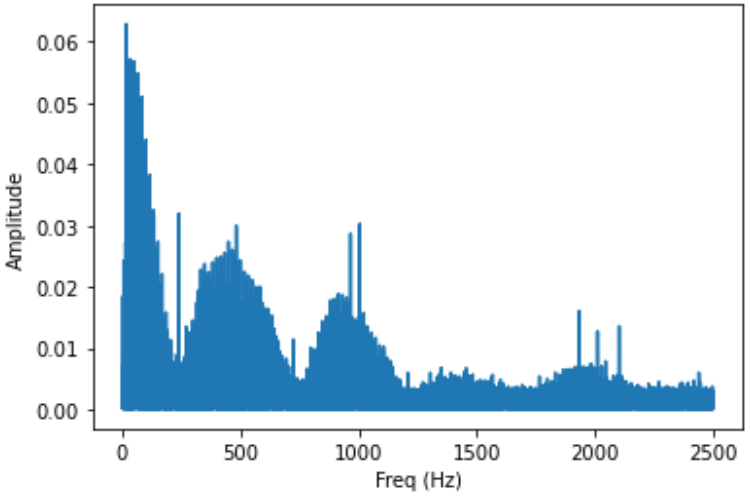


I/O consumption



Software consumption





Feature extraction

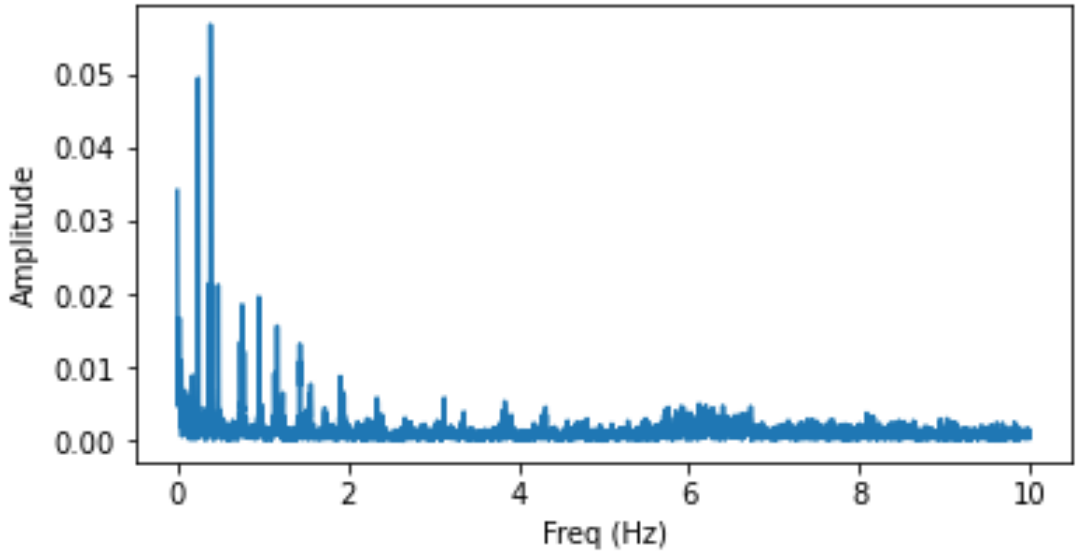
- Context
- Data sets
- Features
- Electronic board
- Anomaly detection

- Statistical features
- Frequency features

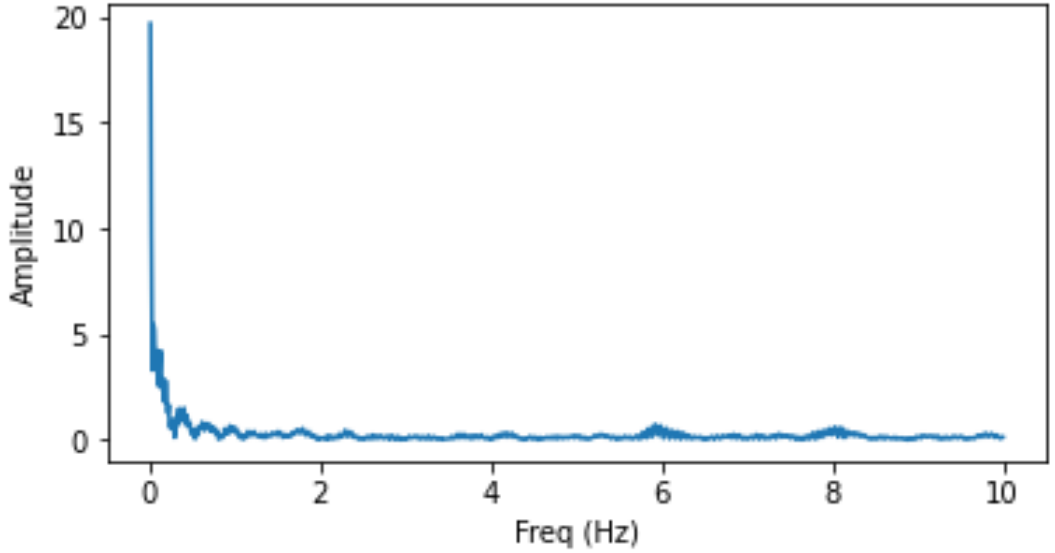
> Latch-up frequency spectrum calculated using laser data set.

> At the time, acquisition frequency limited to 10Hz

> During latch-up, vanishing of frequency peaks



Frequency spectrum in normal conditions



Frequency spectrum during latch-up

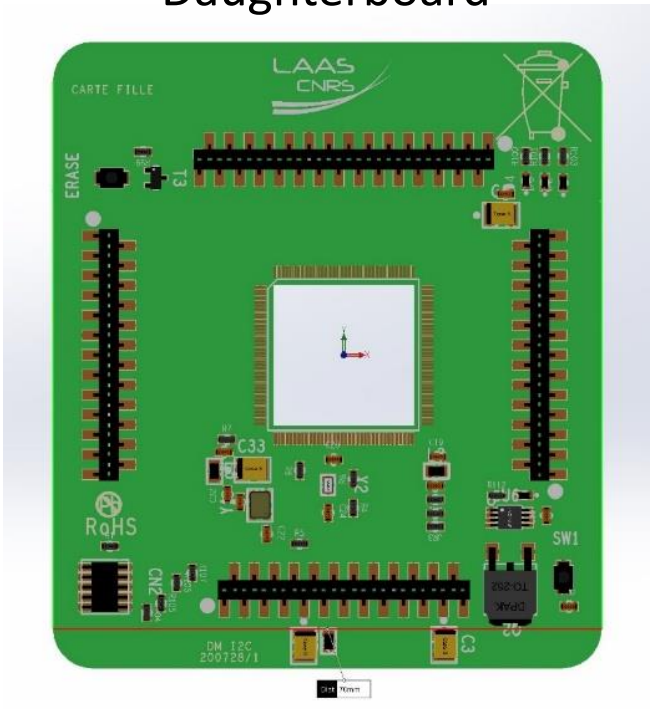
Electronic board

- Context
- Data sets
- Features
- Electronic board
- Anomaly detection

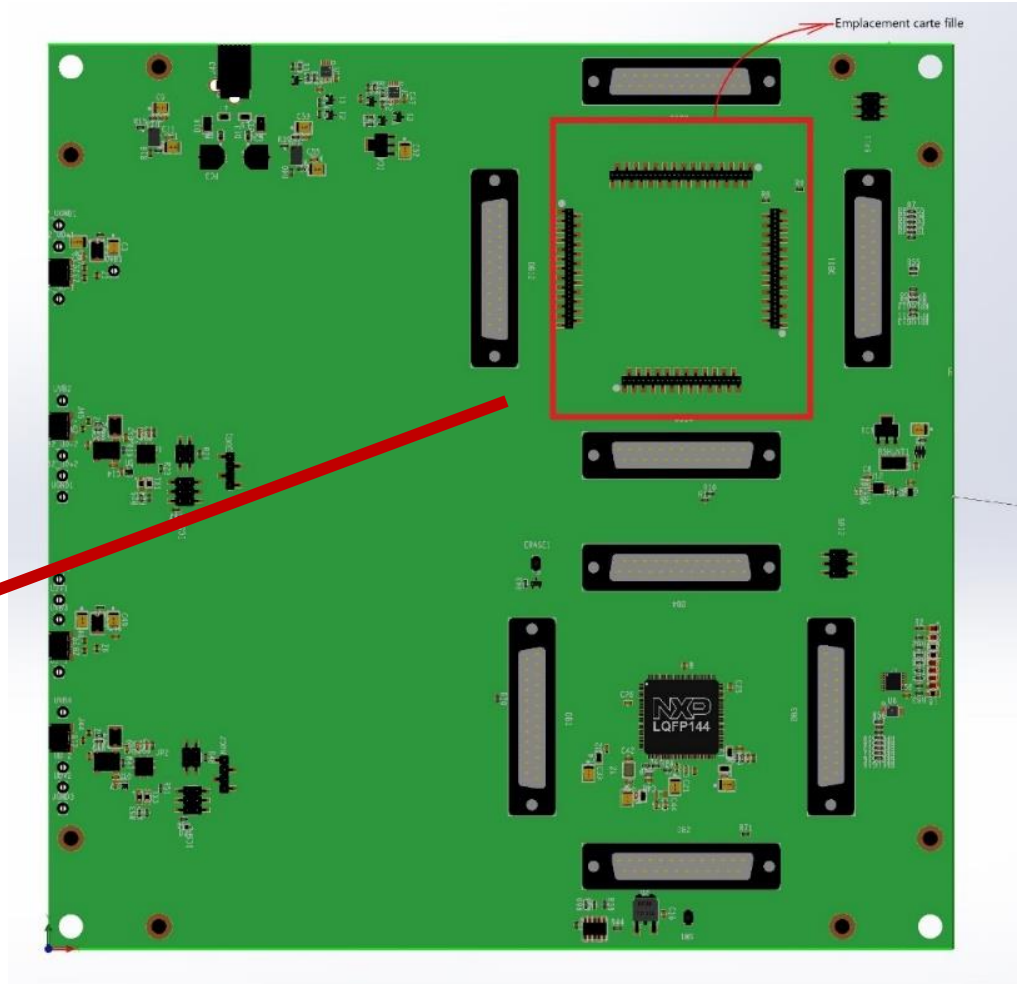
> Creation of a board specifically designed latch up data set creation

> Mother/daughter board system to replace easily the Device Under Test in case of damage

Daughterboard



Motherboard

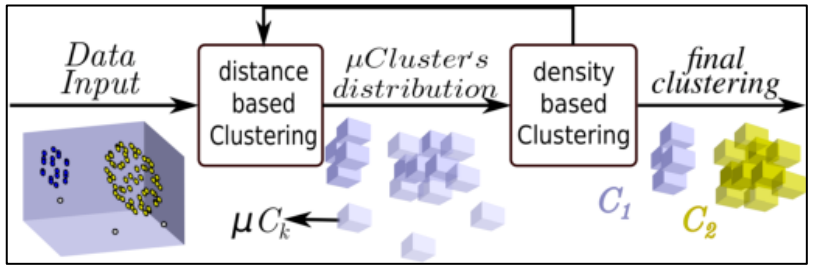


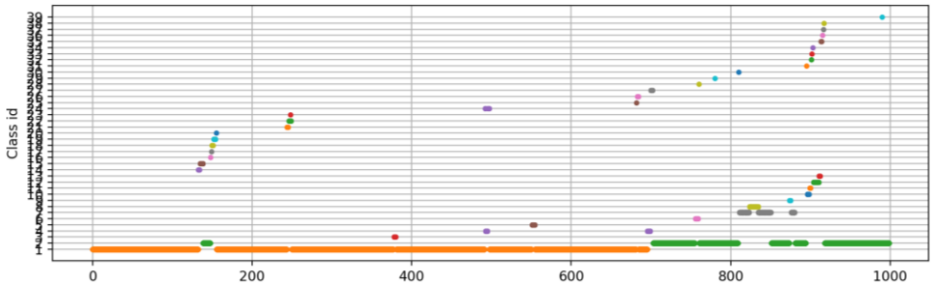
Anomaly Detection

- Context
- Data sets
- Features
- Electronic board
- Anomaly detection

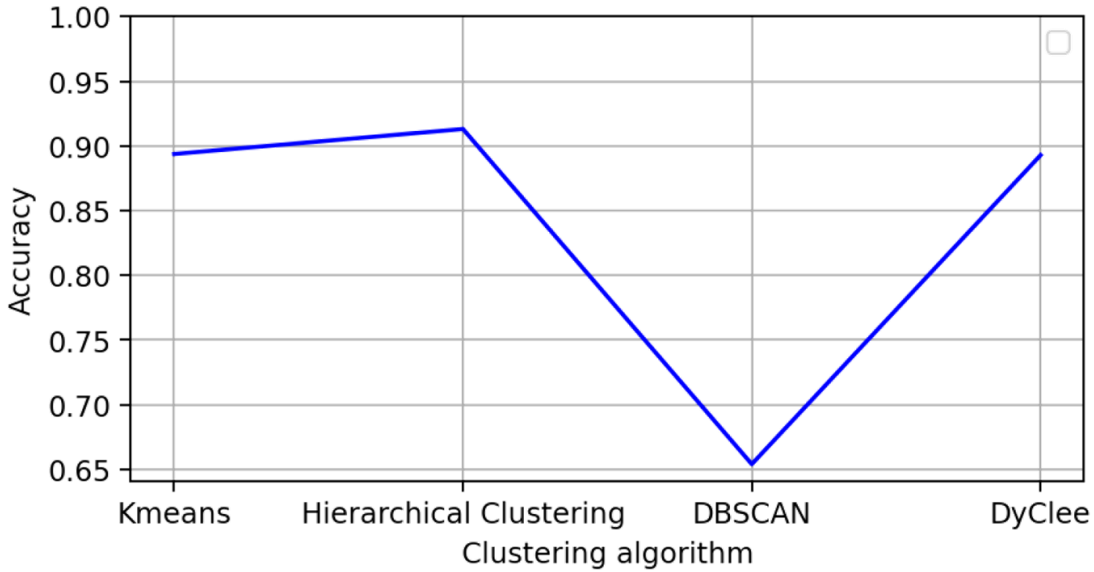
Dyclee

- DyClee is an algorithm developed by DISCO team in Laas
- Distance and density based algorithm with µClusters
- Good results and online learning





Using the features extracted before, we can use learning algorithms to detect latch-up and µLatch-up.



Conclusion

- Context
- Data sets
- Features
- Electronic board
- Anomaly detection

> Data set created to train latch-up detection algorithms
  - Real data sets
  - Simulated data sets

> Features extraction to characterize latch-up anomalies
  - Statistical features
  - Frequency features

> In the future
  - Get more real latch-up data
  - Improve Matlab simulator

References

- Context
- Data sets
- Features
- Electronic board
- Anomaly detection

> Jonas Bikerland Carlsen, Thesis: Design and Validation of Two Single Event Latch-up Protection Solutions: Comparing a New Single Event Latch-up Test Circuit with the IDEAS IDE3466 Single Event Latch-up Detection Module, 2018

> Sébastien Renard. Évaluation des effets des neutrons atmosphériques sur l'électronique embarqué en avionique et recherche de solutions de durcissement. Autre [cond-mat.other]. Université Sciences etTechnologies - Bordeaux I, 2013. Français. NNT : 2013BOR15253. tel-01015741

> Robert Ecoffet: In-orbit anomalies due to radiation. Lessons learnt, ESCCON 2011.

> Nathalie Barbosa Roa, Louise Travé-Massuyès, Victor Hugo Grisales. DyClee: Dynamic clustering for tracking evolving environments. Pattern Recognition, Elsevier, 2019, 94, pp.162-186.10.1016/j.patcog.2019.05.024.

> INVAP/Roberto Manuel CIBILS: Method for updating the reference threshold of at least one operational parameter, protection unit for the mitigation of a single event latchup (SEL) in an electronic device using the reference threshold and arrangement for the mitigation of a single event latchup (SEL) in an array.

Thank you !

adrien.dorise@laas.fr