



DE LA RECHERCHE À L'INDUSTRIE



# EPICS MODULES TOOLKIT FOR RF TEST STANDS

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[www.cea.fr](http://www.cea.fr)



## CEA IRFU Involved in the control system of the following projects :

- IFMIF : Injector, diagnostics, cavities.
- ESS : Injector, cavities couplers conditioning, test cavities demonstrator
- SARAF: Injector, cavities couplers conditioning, test cavities, rebuncher...
- ...

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## Similar needs :

- Analysis of the RF signal
- Automatic RF conditioning sequence.

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## Conditioning concept

« *All existing high power couplers exhibit severe outgassing and multipacting barriers of vacuum and RF exposed surfaces, as a result of geometrical configurations and surface conditions (material, contaminants, finishing).* »

*These problems can be overcome by design and different procedures like cleaning, baking followed by RF Conditioning -application of RF power under various conditions and in various configurations:*

- *Pulsing the RF with different duty factors*
- *In continuous wave mode (CW)*
- *as traveling wave mode*
- *as standing wave mode*
- *Sweeping of frequency or RF power amplitude*

*Objective: to clean the surfaces from contaminants (molecular or particulate) and minimize conditions for multipacting. During this process the QA of different coupler components and associated instrumentation is obtained. »*

**Mircea Stirbet (Jefferson Lab)**  
**RF Conditioning: Systems and Procedures**

$$\left(\frac{\partial v}{\partial t} + v \cdot \nabla v\right) = -\nabla p + \nabla \cdot T + f$$

$$H = -\sum p(x) \log p(x)$$

$$\frac{1}{2} G^2 S^2 \frac{\partial^2 V}{\partial S^2} + r S \frac{\partial V}{\partial S} + \frac{\partial V}{\partial t} - r \cdot V = 0$$

$$TC(Q, q_i, m_i) = \sum_{i=1}^n \left[ \frac{D_i}{m_i q_i} S_{i+1} + c_i v D_i + \frac{q_i H_i^v}{2} \left( m_i \left( 1 - \frac{D_i}{P_i} \right) - 1 + 2 \frac{D_i}{P_i} \right) \right]$$

$$\begin{bmatrix} \frac{d \Delta p(s, \phi)}{d \phi} \\ \frac{d \Delta M(s, \phi)}{d \phi} \end{bmatrix} = \begin{bmatrix} \alpha & -\beta \\ \gamma & 0 \end{bmatrix} \begin{bmatrix} \Delta p(s, \phi) \\ \Delta M(s, \phi) \end{bmatrix}$$

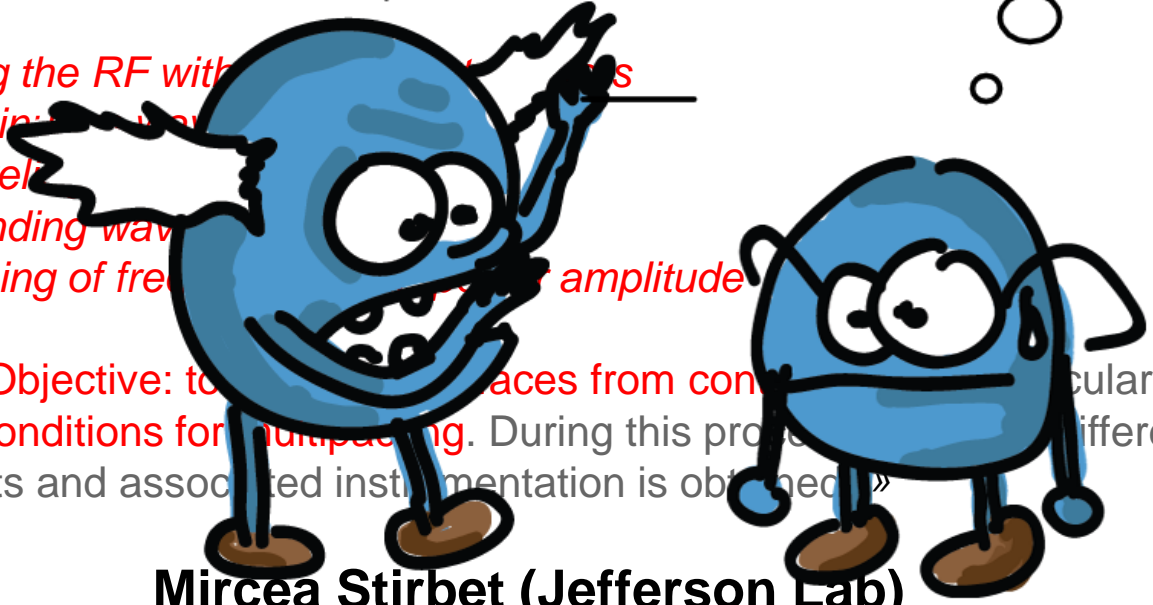
ere outgassed  
ult of ge



cleaning, baking, etc.  
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## CEA IRFU standard method.

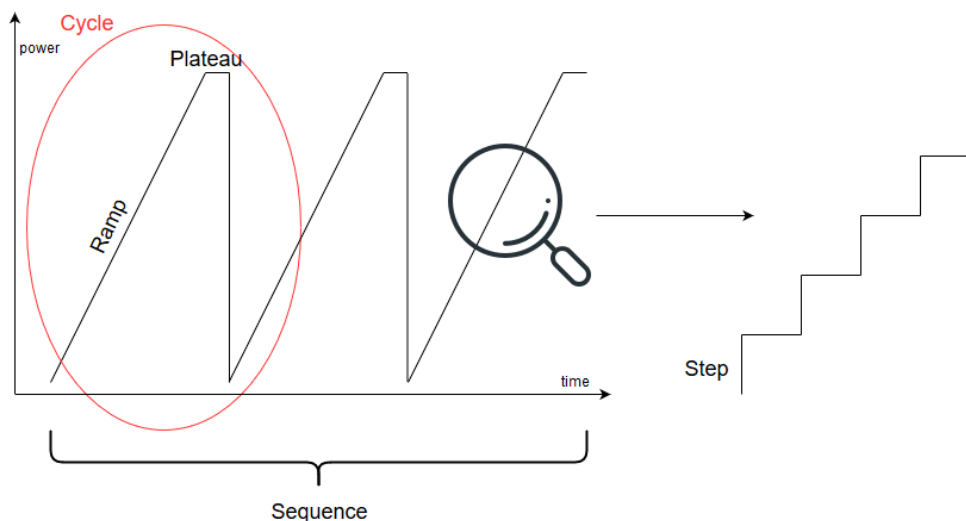
A **conditioning sequence** is composed of a set of **cycles** with the RF pulse width increased at each cycle.

A **cycle** is defined by a RF pulse width and is composed of a **RF power ramp** terminated by a **plateau**.

A **RF power ramp** is composed of a set of **steps** with the RF power increased at each step.

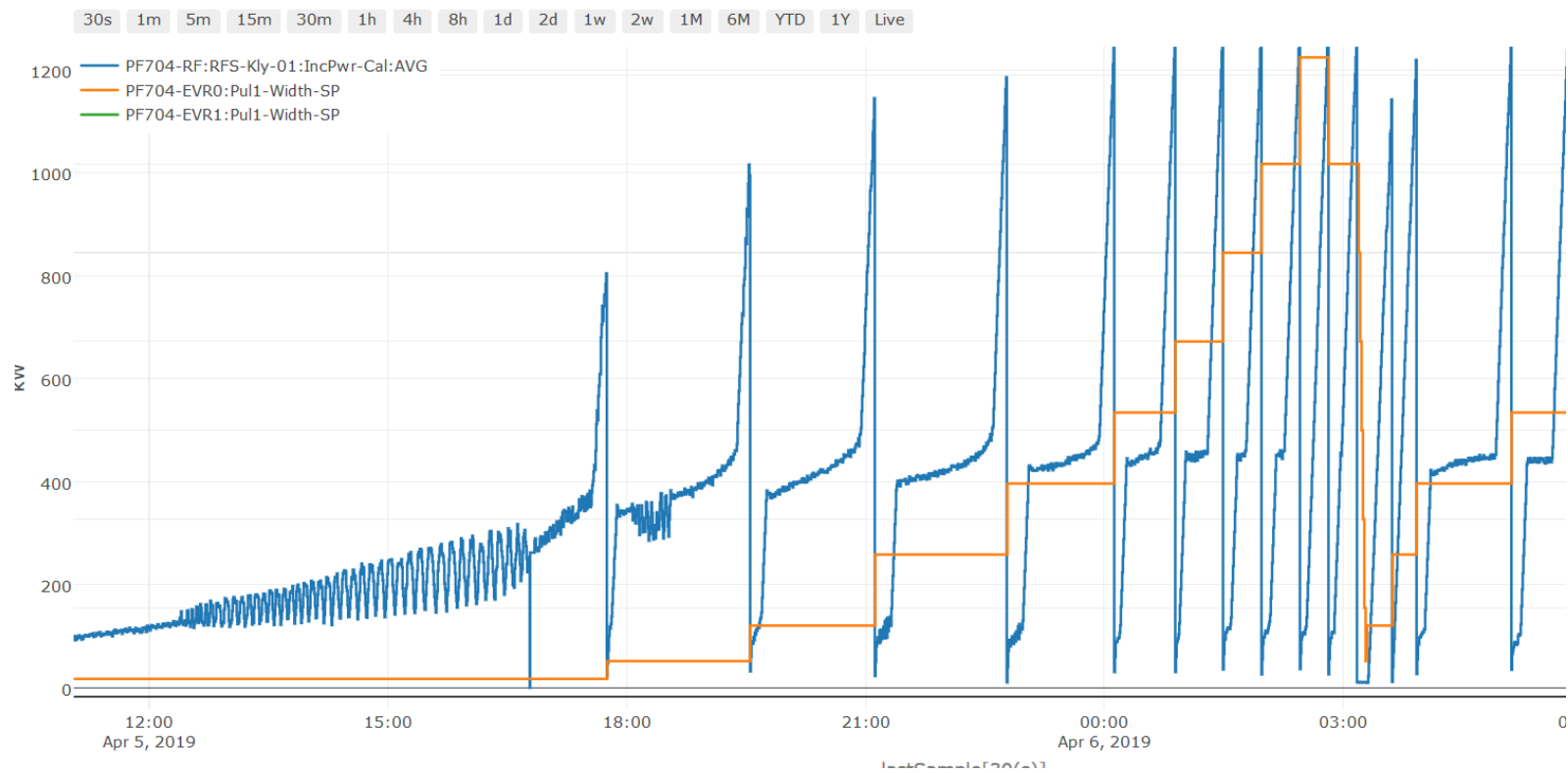
A **step** is defined by a RF power value and a number of RF pulses.

A **plateau** is defined by a RF power value and a number of RF pulses.



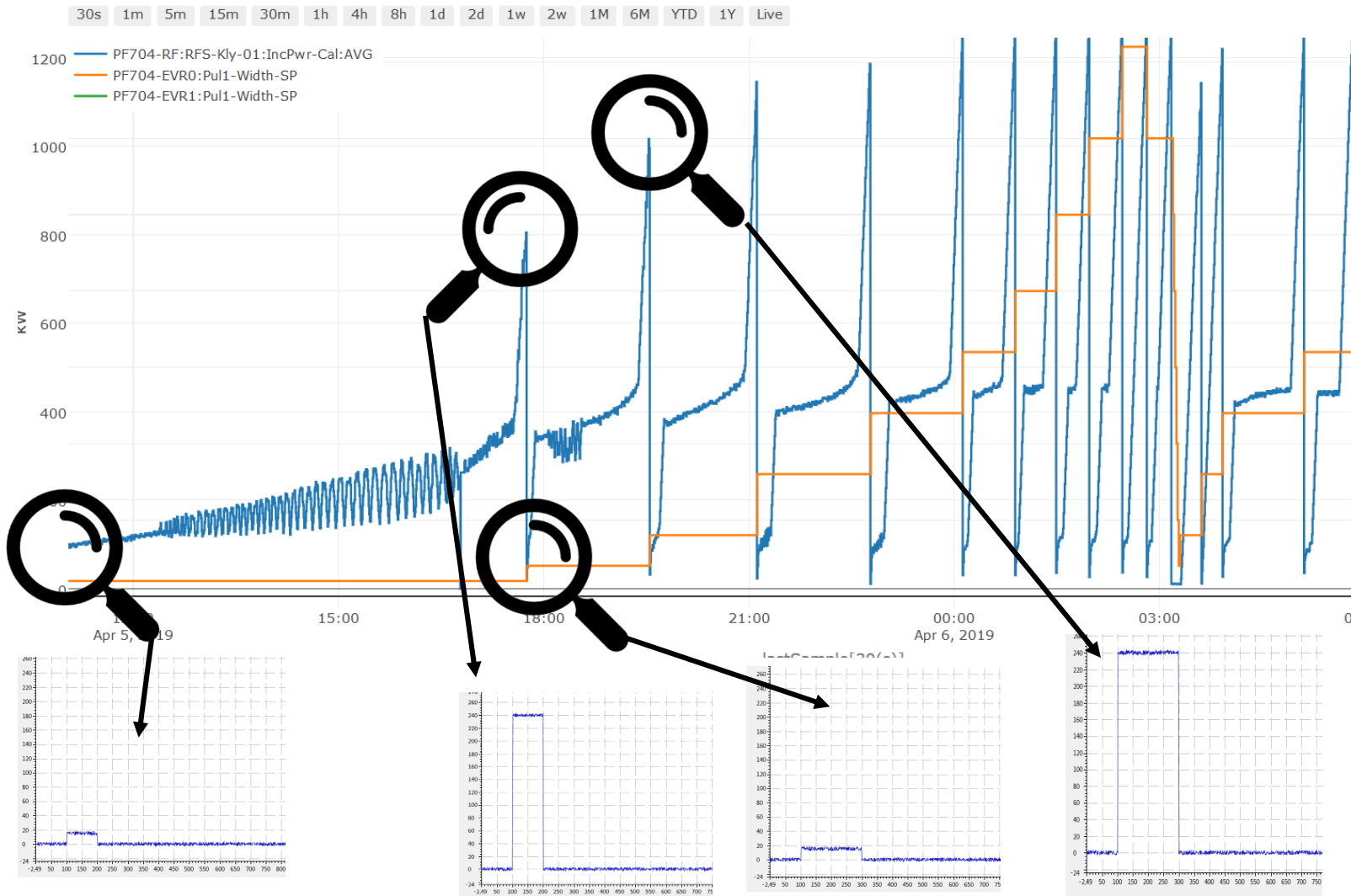
If the vacuum/temperature/leak (PM/Pue-) defect happen we insist on the zone, by pausing the RF power or decreasing it

## Example





## Example



**CalibrationApp** : is a support application module that allows to **convert** signal data contained in **waveform**.

- Breakpoint table EPICS (non linear conversion)
  - Standard
  - Apply to RF power signal conversion
  - Apply to Cavity field
- Polynomial function

```
file calibBPTPwr.template
{
  pattern
  {SIGNAL,
    ,NELM,RAWL,RAWH,EGU,PREC,BPT}
  {"PF352-RF:RFS-KCirc-01:IncPwr" ,16000,0,10,kW,3,typeVtoDbmPCIRDIR}
  {"PF352-RF:RFS-KCirc-01:RefPwr" ,16000,0,10,kW,3,typeVtoDbmPCIRREF}
  {"PF352-RF:RFS-Kload-01:IncPwr" ,16000,0,10,kW,3,typeVtoDbmPLOC DIR}
}
```

- \$(SIGNAL)-Cal : waveform calibrated
- Records to configure signal (attenuation, field cavity, polynomial degree...etc)



**ConditioningSeq** : is a support application module that allows to execute a sequence of RF conditioning.

```
epicsEnvSet ("power", "PF704-RF:RFS-KAtt-01:kW")
epicsEnvSet ("count", "PF704-RF:RFS-Kly-01:IncPwr-Cal:Trig")
epicsEnvSet ("width", "PF704-EVR0:Pull-Width-SP")
epicsEnvSet ("major", "PF704-Cpl:DefaultMajor")
epicsEnvSet ("minor", "PF704-Cpl:DefaultMinor")
epicsEnvSet ("critic", "PF704-Cpl:DefaultCritic")
epicsEnvSet ("exp", "PF704-Cpl:Conditionning-01")

seq ConditionningWF "power=$(power), countPulse=$(count), width=$(width),
defaultMajor=$(major), defaultMinor=$(minor), defaultCritic=$(critic), Experiment=$(exp)"

dbLoadRecords ("SeqConditionning.template", "EXPERIMENT=PF704-Cpl:Conditionning-01")
```

- Records to configure and monitor the sequence
- Handle generic defaults :
  - Minor : pause the RF.
  - Major : decreasing the RF
  - Critical : Stop the all sequence

**ConditioningSeq** : is a support application module that allows to execute a sequence of RF conditioning.

```

epicsEnvSet ("power", "PF704-RF:RFS-KAtt-01: kW")
epicsEnvSet ("count", "PF704-RF:RFS-Kly-01: IncPwr-Cal: Trig")
epicsEnvSet ("width", "PF704-EVR0: Pull-Width-SP")
epicsEnvSet ("major", "PF704-Cpl: DefaultMajor")
epicsEnvSet ("minor", "PF704-Cpl: DefaultMinor")
epicsEnvSet ("critic", "PF704-Cpl: DefaultCritic")
epicsEnvSet ("exp", "PF704-Cpl: Conditioning-01")

seq ConditioningWF "power=${(power)} countPulse=${(count)} width=${(width)}
defaultMajor=${(major)}, default #Default major for the conditioning sequence :decrease power
record(calc, "${(SECTION)}-${(SUBSECTION)}: DefaultMajor") {
dbLoadRecords ("SeqConditionni field(INPA, "${(SECTION)}-${(SUBSECTION)}: VAC-PwrC-01: PresDefault CPP")
field(INPB, "${(SECTION)}-${(SUBSECTION)}: VAC-PwrC-02: PresDefault CPP")
field(INPC, "${(SECTION)}-${(SUBSECTION)}: VAC-PwrC-03: PresDefault CPP")
field(INPD, "${(SECTION)}-${(SUBSECTION)}: VAC-PwrC-04: PresDefault CPP")
field(INPE, "${(SECTION)}-${(SUBSECTION)}: VAC-Ves-01: PresDefault CPP")
field(INPF, "${(SECTION)}-${(SUBSECTION)}: VAC-Cav-01: PresDefault CPP")
field(INPG, "${(SECTION)}-${(SUBSECTION)}: VAC-Cpl-01: Pres. SEVR CPP")
field(INPH, "${(SECTION)}-${(SUBSECTION)}: VAC-Cpl-02: Pres. SEVR CPP")
field(INPI, "${(SECTION)}-${(SUBSECTION)}: VAC-Cpl-03: Pres. SEVR CPP")
field(INPJ, "${(SECTION)}-${(SUBSECTION)}: VAC-Cpl-04: Pres. SEVR CPP")

field(CALC, "(!(A && B && C && D && E && F)) || ((G + H + I +J)>0?1:0)")
field(PINI, "YES")
}

```

- Records to configure a
- Handle generic default
  - Minor : pause the
  - Major : decreasing
  - Critical : Stop the

**SaveRestoreApp** : is a support application module that allows to save or restore the current state of a list of PVs.

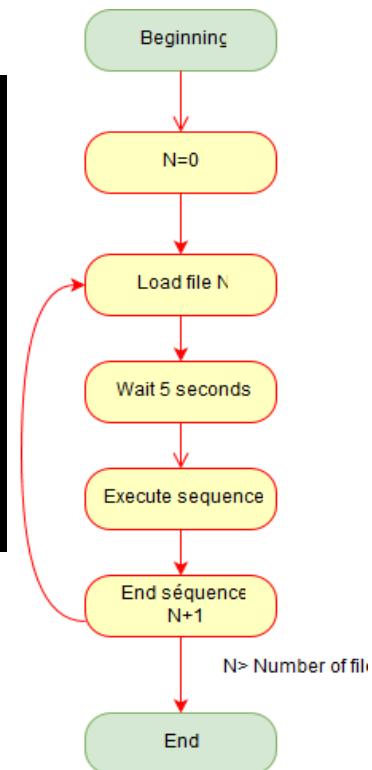
- Based on autosave file format (and code)
  - \*.sav file
  - \*.req file
- save/restore operations performed by IOC records
- Restore SNL sequence for sub-sequence

```
epicsEnvSet("defect", "PF704-Cpl:DefaultCritic")
epicsEnvSet("loadFile", "PF704-Cpl:Conditionning-01:PathSav")
epicsEnvSet("start", "PF704-Cpl:Conditionning-01:Rdy-Seq")
epicsEnvSet("exp", "PF704-Cpl:Conditionning-01")

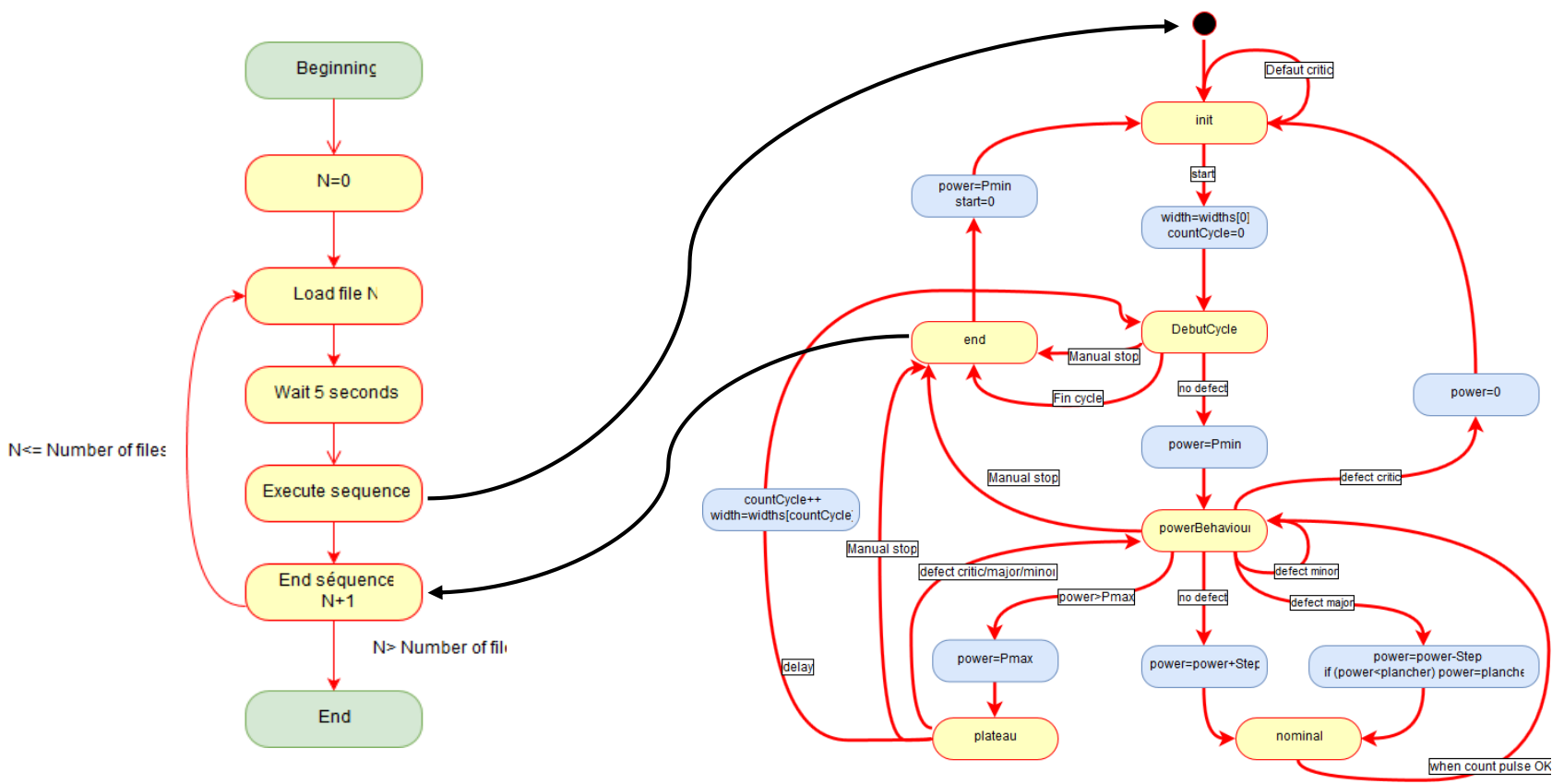
seq SequenceLoad
"defect=$(defect),loadFile=$(loadFile),isSeqStarted=$(start),Experiment=$(exp)"

dbLoadRecords("SaveRestoreC.template", PREFIX=PF704-Cpl:Conditionning-01)
dbLoadRecords("SeqLoad.template", EXPERIMENT=PF704-Cpl:Conditionning-01)
```

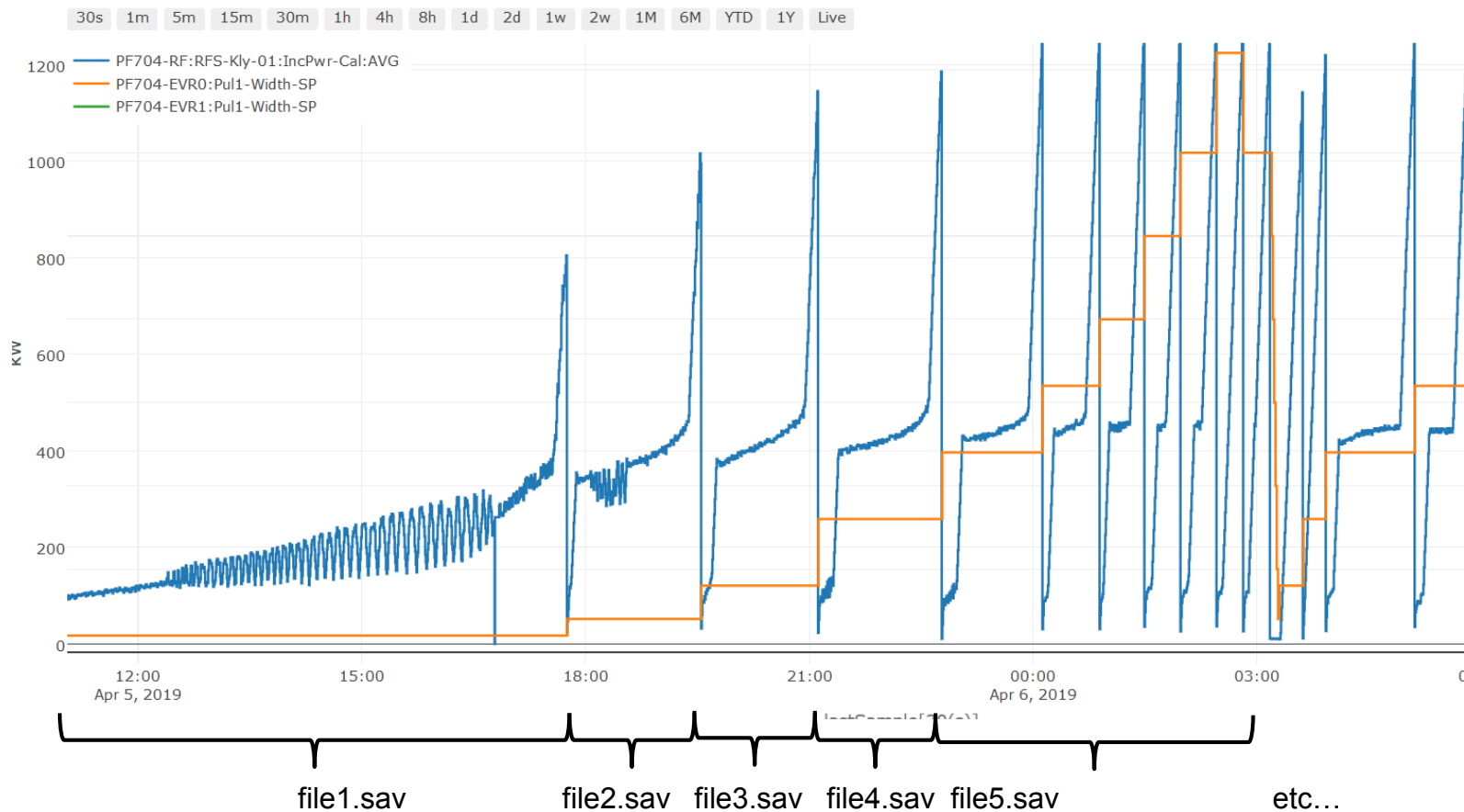
- Records to configure and execute the sequence



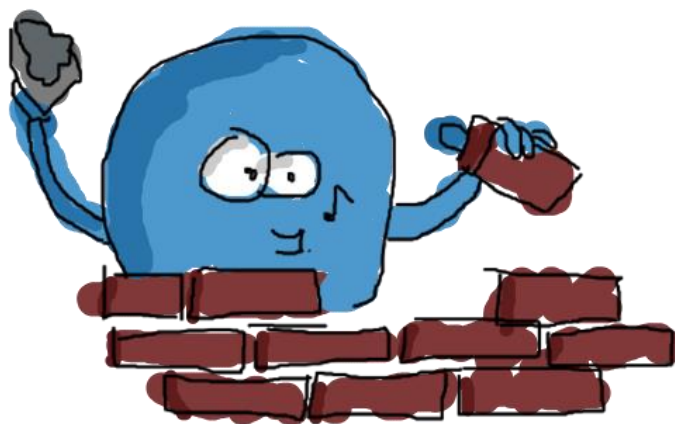
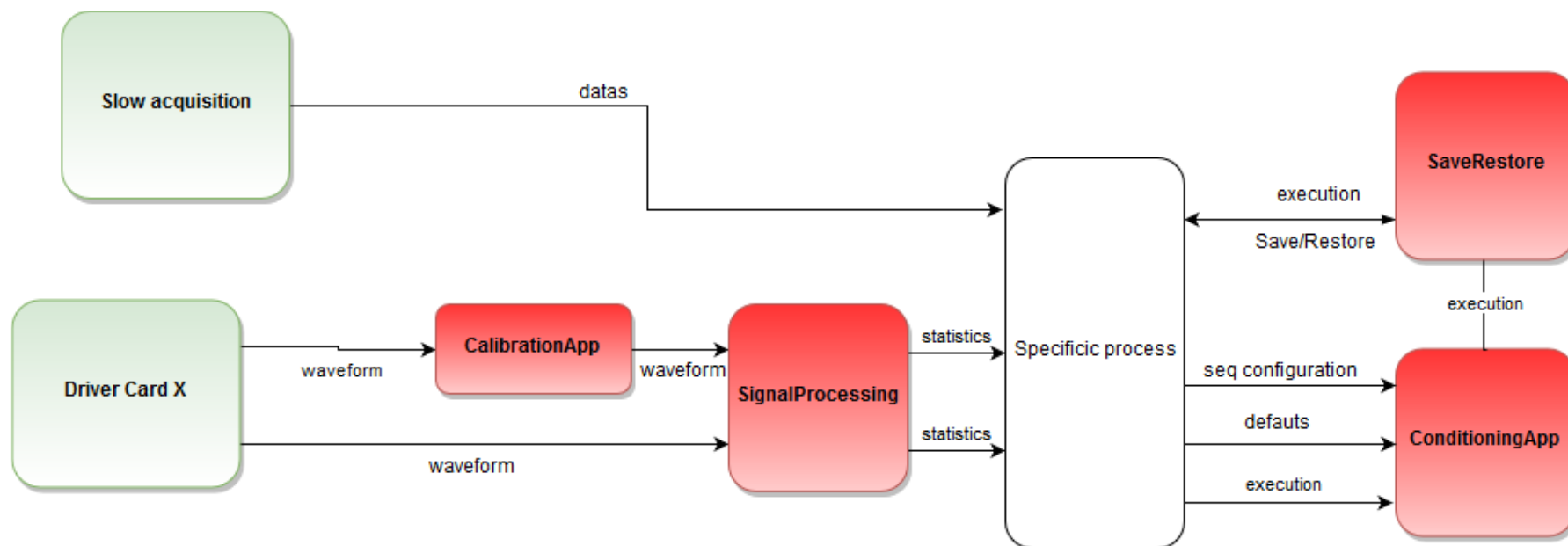
## SaveRestoreApp + ConditioningSeq



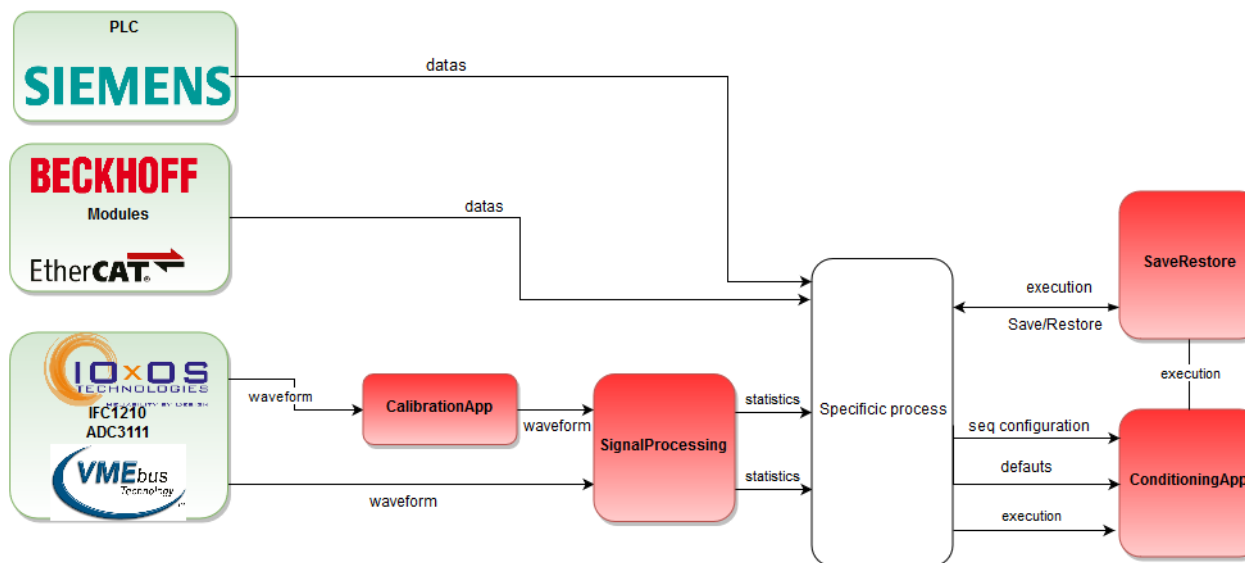
## SaveRestoreApp + ConditioningSeq



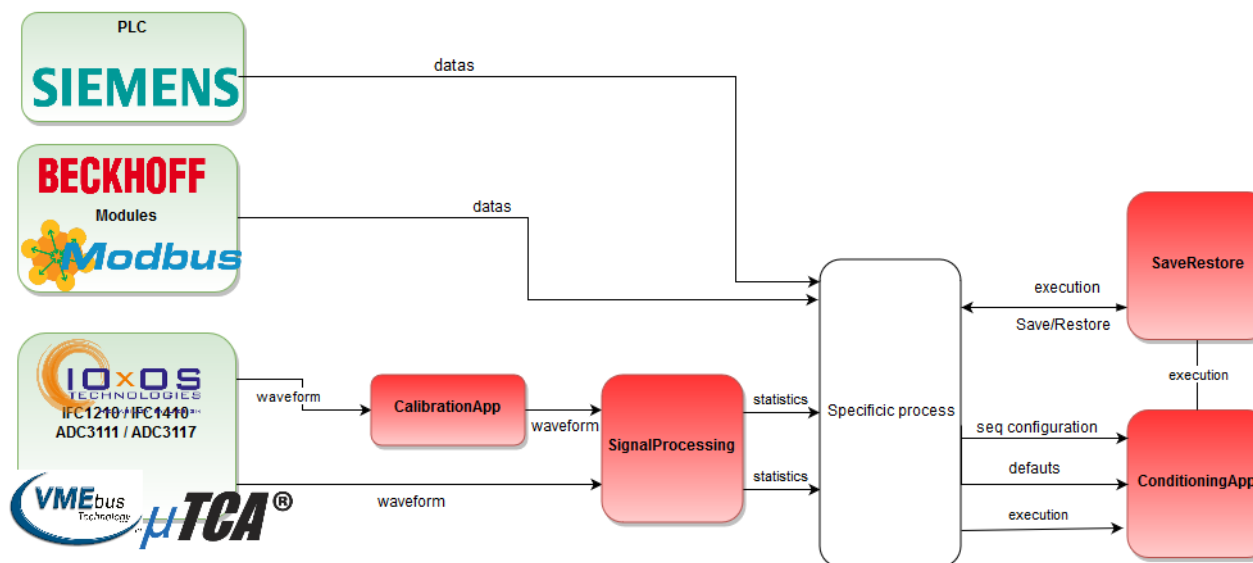




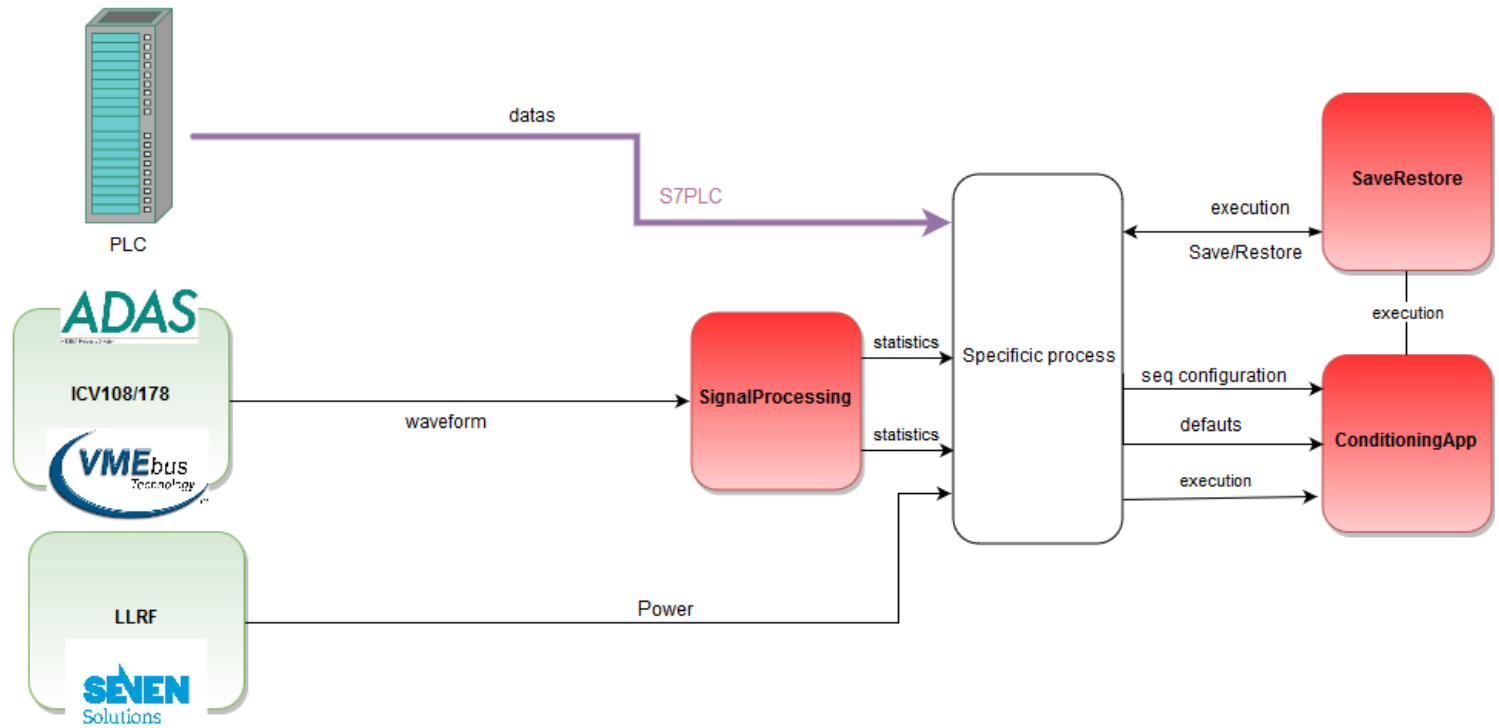
ESS  
test stands



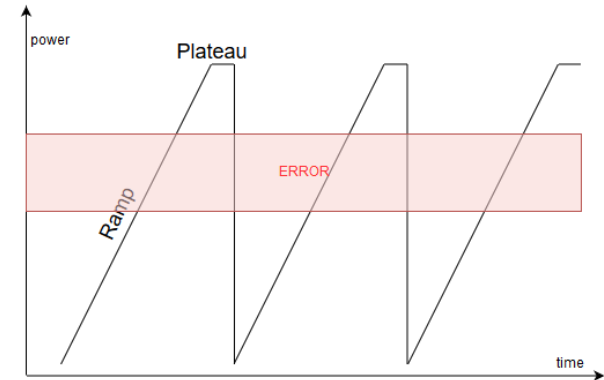
SARAF  
test stands



## IFMIF Cryomodule



- IFMIF :
  - Coupler 7 can't handle some power area



- ✓ Monitor the power in the sequence -> can apply some external rules (calcout, aSub, other clients...)

# Demo (if gif can be displayed...)

### Configuration cycle

Min

Max

Plancher

Step up

Step down

Widths

Max width

Step time

Plateau time

infinite cycle

Execution

### Simu

Power

Samples

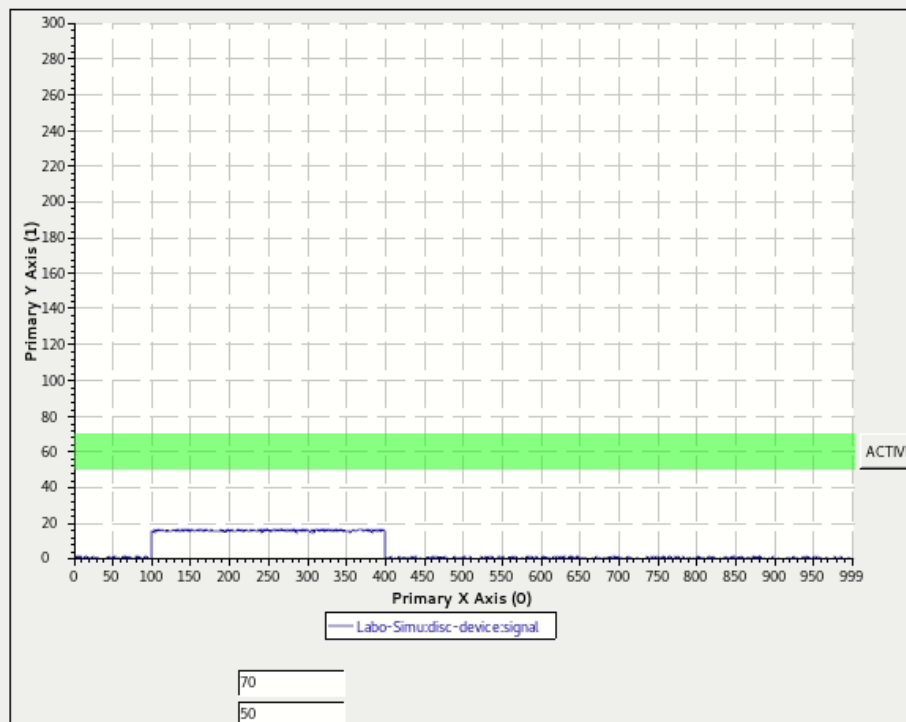
Pretrig

WidthRB

minor  major  critic

Frequency

En cours : 0.0



0

# ECCTD ESS

Will be introduced at ICALEPCS

Menu
Conditionnement Coupleur

Pilotage RF
Distribution RF
Coupleur1
Coupleur2
Coupleur3
Coupleur4

**Graphiques**

Puissances inc / ref

Tension Cavité

PickUp/PM

**Cavité 2**

TEMP2 292,45 K

Vide Iso 0E0 mBar

VCAV 0,00E0 mBar

CAVITE X 0,1000 µSv/h

**Interlocks**

- PUE ●
- PMV ●
- PMA ●
- Vide coupleur ●
- Vide iso ●
- Vide cavité ●
- Cryo ●
- PKREF ●
- Eau ●
- Porte ●
- Rayon X ●

**Affichage**

Détache

**Sauvegarde séquence**

Sauver
Charger

**Seuils sécurité**

PUE	<input style="width: 80%;" type="text" value="0,0000 v"/>
PMV	<input style="width: 80%;" type="text" value="9,9900 v"/>
PMA	<input style="width: 80%;" type="text" value="9,9900 v"/>

**Sequence conditionnement**

Min	<input style="width: 80%;" type="text" value="10 kW"/>
Max	<input style="width: 80%;" type="text" value="100 kW"/>
Plancher	<input style="width: 80%;" type="text" value="20 kW"/>
Pas montée	<input style="width: 80%;" type="text" value="10 kW"/>
Pas descente	<input style="width: 80%;" type="text" value="10 kW"/>
Steps	<input style="width: 80%; background-color: red;" type="text"/>
Durée palier	<input style="width: 80%;" type="text" value="0,00 s"/>
Durée Plateau	<input style="width: 80%;" type="text" value="0,00 s"/>
Dernier cycle infini	<input checked="" type="checkbox"/>
Fréquence de répétition	<input style="width: 80%;" type="text" value="1,00 Hz"/>

**Type Séquence**

▶
Avancée

● Arrêté.

**Conditionnement**

- Test cavité
- Configuration
- Scope numérique
- Timing
- RawValue

**Interlocks**

- Vide iso ●
- Vide cavité ●
- Cryo ●
- Porte ●
- Rayon X ●
- Coupleur 1 ●
- Coupleur 2 ●
- Coupleur 3 ●
- Coupleur 4 ●

**Sécurité X**

NEUTRON	0,0010 µSv/h
CAVITE	0,1003 µSv/h
XRAY	0,0994 µSv/h

**Synthe RF**

**Acquittement BAIE ECCTD** ACQ

**Acquittement BARGE 704** ACQ

# SARAF Rebuncher Test Stand (F. Gohier, Y. Lussignol)

The image displays a comprehensive control interface for the SARAF Rebuncher Test Stand, organized into several functional panels:

- SARAF Rebuncher Test Stand:**
  - Configuration:** Includes buttons for RF Control, Tuner Control, Data Acquisition, RF Conditioning, and Interlock.
  - Status Indicators:** XRay, Door, FlowA, Flow1-4, UIncStat, URefStat, UTrsStat, PUEStat, and VacStat.
  - Temperatures:** Temp1 (52.1 °C), Temp2 (41.0 °C), Temp3 (71.7 °C).
  - Rebuncher:** Central component with associated VacMes (2.3E-8 mbar) and PUE.
  - Defects/Alarms/Interlocks:** All shown as NO\_ALARM or ACK.
- RF Power Plots:**
  - Pulse:** Width 0.00 ms, Effective width 0.00 ms.
  - UIncMes:** Average 0.00 mW, Max 0.00 mW, Min 0.00 mW.
  - PUeMes:** Average 5.59 V, Max 5.59 V, Min 5.59 V.
  - URefMes:** Average 0.00 kW, Max 0.00 kW, Min 0.00 kW.
- RF Control:**
  - RF Output:** RF ON, Frequency 0.009 MHz, Level 0.000 kW.
  - Pulse:** Pulse Modulation ON, Pulse Generator ON, Frequency 10,000 Hz, Pulse Width 0.020 s.
- RF Conditioning:**
  - Pulse Width:** From 10.0 ms to 40.0 ms, Arithmetic Progression 5.0 ms.
  - RF Power:** From 10,000 kW to 30,000 kW, Floor 15,000 kW, Arithmetic Progression 1.20.
  - Defects/Alarms/Interlocks:** Defects NO\_ALARM, Alarms NO\_ALARM, Pulses count 70.
  - State:** IDLE, Remaining time 14 s.
- Configuration:**
  - Vac/Temp/Water / RF Power / Calibration / Save/Restore:** Graph showing Vrms vs time with multiple data series.
  - Summary:** UIncMes (V full: 10,000, V offset: 0.100, Average: 1.626), URefMes (V full: 10,000, V offset: 0.300, Average: 1.887), UTrsMes (V full: 10,000, V offset: 0.000, Average: 1.648).
- Data Acquisition:**
  - Sample rate:** 2.50E5 (2,500,000) samp/s.
  - N samples:** 16384.
  - Pre-trigger:** 0.
  - Master signal compression Factor:** 16.
  - Slave signals decimation Factor:** 1.
  - Slave signals compression Factor:** 1.
  - Buttons:** ON, RUN, RUNNING.
  - Trigger counter:** 1503.
- Interlock:**
  - Buttons:** ACK, Flow1, Flow2, Flow3, Flow4, FlowA, XRay, Door, UTrsStat, UIncStat, URefStat, PUEStat, VacStat.

## ESS :

- Coupler Cavities Test stand (x2)
- RFQ couplers
- ECCTD : Elliptical Cavities and Cryomodule Test stand Demonstrator
- RFQ Conditioning (sequence used by E. Trachanas)

## Saraf:

- C2TS : Coupler cavities Test Stand
- ECTS : Equiped Cavities Test Stand
- RBTS : Rebuncher Test stand
- Cryomodules (future)

## IFMIF LIPAC:

- Sathori : Equiped Cavities test stand
- SRF : Cryomodule conditioning on site



Thanks for your attention



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