



Elettra  
Sincrotrone  
Trieste





Elettra Sincrotrone Trieste

# Elettra Sincrotrone Trieste Italy laboratory

*Elettra is a multidisciplinary international research center of excellence,  
specialized in generating high quality synchrotron and free-electron laser  
light and applying it in materials and life sciences*



# ELETTRA: Storage Ring Synchrotron

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1993: 2.0-2.4 GeV (310/160mA)  
Storage Ring

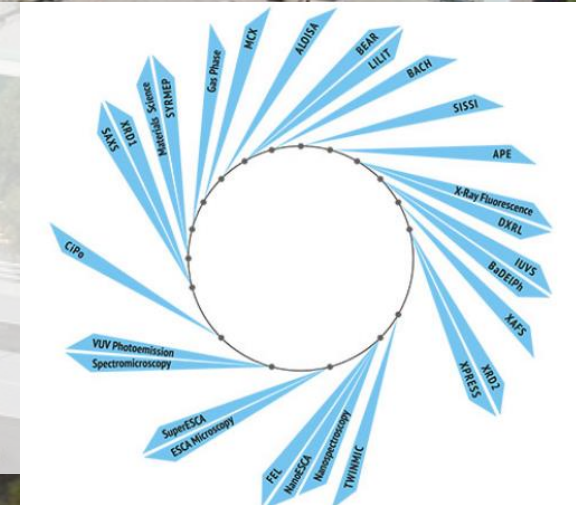


## Upgrade project: Elettra2.0

- 2-2.4 GeV 400mA storage ring
- Reduced emittance for increased brilliance and coherence
- Time schedule: 2025-2026

## 28 VUV-Xrays beamlines

- Spectroscopy
- Spectromicroscopy
- Diffraction
- Scattering and lithography
- Infrared microscopy and spectroscopy
- Ultraviolet inelastic scattering



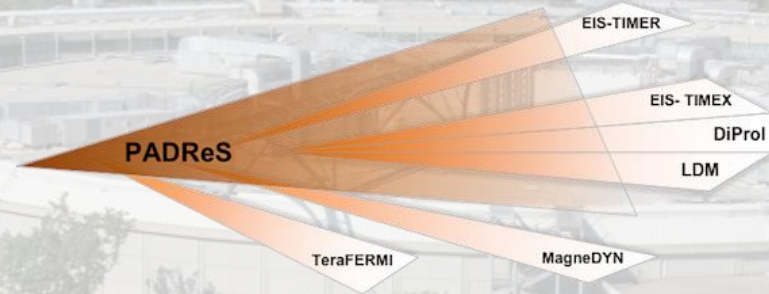


# FERMI: Free Electron Laser (FEL) - 2010

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Free Electron Laser source:

- “Seed” by a conventional laser
- high peak power (>GWs)
- short pulse length (<100 fs)
- full spatial and temporal coherence
- photon energy bandwidth <  $10^{-3}$
- tunable wavelength (100-4 nm)
- variable polarization



1.5 GeV electron linear accelerator



Two undulator lines: FEL-1 and FEL-2



Experimental hall with 6 end stations



# Sequencers

High-level automation based on "Behavior Trees".

Ref.:

A Framework for High Level Machine Automation Based on Behavior Tree,  
<https://accelconf.web.cern.ch/icalepcs2021/doi/JACoW-ICALEPCS2021-WEAL02.html>

G. Gaio, P. Cinquegrana, S. Krecic, G. Scalamera, G. Strangolino, F. Tripaldi, M. Trovò, L. Zambon  
Elettra-Sincrotrone Trieste S.C.p.A., Basovizza, Italy

# the constraints of client-side GUIs.

Physicists and operators often need to know the correct sequence of actions, which are usually performed through a large number of graphical panels where operations are "embedded" in client-side code, thereby limiting the level of automation that a control system can achieve.

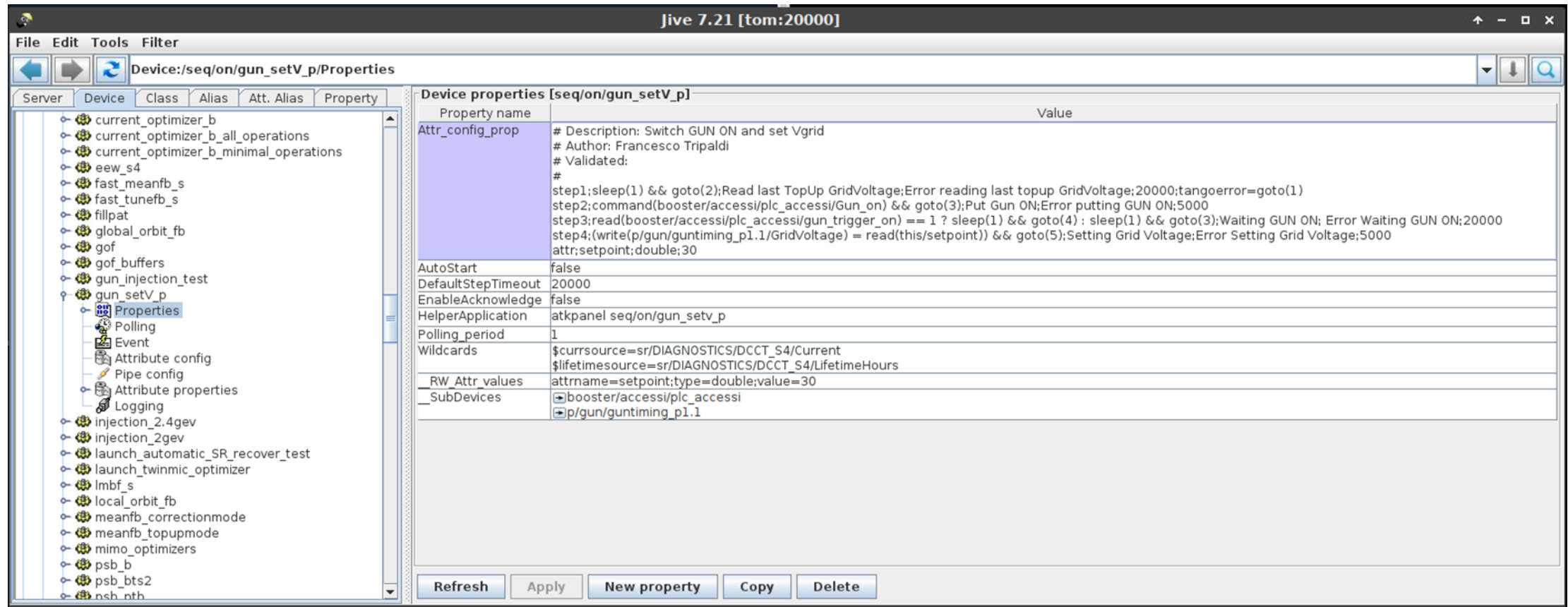
As a result, it's very challenging to determine the optimal sequence of actions required to perform a task, making the accelerator's performance dependent on the abilities of the physicist/operator.

# Sequencer: a high-level automation framework based on "Behavior Trees".

- Inspired by the recently introduced "behavior trees" in the gaming industry.
- Internally developed by the controls group, they are TANGO device servers.
- Highly complex actions are created, composed of simple autonomous tasks decoupled within a tree structure, regardless of how they are implemented.
- Logic is shifted from GUIs to the server-side, where simple tasks can be easily organized, inspected, and stacked to build more intricate actions.
- They can be created and modified without the need for compilation or server deployment.

# Sequencer: a Tango device

In the Tango control system, devices are created to perform complex actions through operations on other devices or by executing Python or MATLAB code.



The screenshot shows the Jive 7.21 [tom:20000] interface. The left pane displays a tree view of devices, with 'gun\_setV\_p' selected. The right pane shows the 'Device properties [seq/on/gun\_setV\_p]' configuration table.

Property name	Value
Attr_config_prop	# Description: Switch GUN ON and set Vgrid # Author: Francesco Tripaldi # Validated: # step1:sleep(1) && goto(2);Read last TopUp GridVoltage;Error reading last topup GridVoltage;20000;tangoerror=goto(1) step2:command(booster/accessi/plc_accessi/Gun_on) && goto(3);Put Gun ON;Error putting GUN ON;5000 step3:read(booster/accessi/plc_accessi/gun_trigger_on) == 1 ? sleep(1) && goto(4) : sleep(1) && goto(3);Waiting GUN ON; Error Waiting GUN ON;20000 step4:(write(p/gun/guntiming_p1.1/GridVoltage) = read(this/setpoint)) && goto(5);Setting Grid Voltage;Error Setting Grid Voltage;5000 attr;setpoint;double;30
AutoStart	false
DefaultStepTimeout	20000
EnableAcknowledge	false
HelperApplication	atkpanel seq/on/gun_setv_p
Polling_period	1
Wildcards	\$currsource=sr/DIAGNOSTICS/DCCT_S4/Current \$lifetimesource=sr/DIAGNOSTICS/DCCT_S4/LifetimeHours
_RW_Attr_values	attrname=setpoint;type=double;value=30
_SubDevices	booster/accessi/plc_accessi p/gun/guntiming_p1.1

Buttons at the bottom: Refresh, Apply, New property, Copy, Delete.



# Sequencers: the base syntax

## Incremental step

```
# Description: Switch GUN ON and set Vgrid
# Author: Francesco Tripaldi
# Validated:
#
step1;sleep(1) && goto(2)
step2;command(booster/accessi/plc_accessi/Gun_on) && goto(3);Put Gun ON;Error putting GUN ON;5000
step3;read(booster/accessi/plc_accessi/gun_trigger_on) == 1 ? sleep(1) && goto(4) : sleep(1) && goto(3)
step4;(write(p/gun/guntiming_p1.1/GridVoltage) = read(this/setpoint)) && goto(5);Setting Grid Voltage;Error Setting Grid Voltage;5000
attr;setpoint;double;30
false
20000
false
atkpanel seq/on/gun_setv_p
1
$currsource=sr/DIAGNOSTICS/DCCT_S4/Current
$lifetimesource=sr/DIAGNOSTICS/DCCT_S4/LifetimeHours
```

Jump to step

Success and error Readout

Timeout

Control structure  
«alternative»  
(if then else)

# Sequencers: the base syntax

```
# Description: Switch GUN ON and set Grid Voltage
# Author: Francesco Tripaldi
# Validated:
#
step1 sleep(1) && goto(2);Read last TopUp GridVoltage;Error reading last topup GridVoltage;20000;tangoerror=goto(1)
step2 command(booster/accessi/plc_accessi/Gun_on) && goto(3);Put Gun ON;Error putting GUN ON;5000
step3;read(booster/accessi/plc_accessi/gun_trigger_on) == 1 ? sleep(1) && goto(4) : sleep(1) && goto(3);Waiting GUN ON; Error Waiting GUN ON;20000
step4; write(p/gun/quntiming_p1.1/GridVoltage) = read(this/setpoint) && goto(5);Setting Grid Voltage;Error Setting Grid Voltage;5000
attr;setpoint;double;30
false
20000
false
atkpanel
1
$currsource=sr/DIAGNOSTICS/DCCT_S4/Current
$lifetimesource=sr/DIAGNOSTICS/DCCT_S4/LifetimeHours
```

**Delay** (points to `sleep(1)`)

**Command to Tango devices** (points to `command(booster/accessi/plc_accessi/Gun_on)`)

**Error catch** (points to `tangoerror=goto(1)`)

**Definition of internal attributes** (points to `attr;setpoint;double;30`)

**Write/Read Tango attributes (external ed internal)** (points to `write(p/gun/quntiming_p1.1/GridVoltage) = read(this/setpoint)`)

**Substitution Wildcards** (points to `$currsource=sr/DIAGNOSTICS/DCCT_S4/Current` and `$lifetimesource=sr/DIAGNOSTICS/DCCT_S4/LifetimeHours`)

# Sequencers of Sequencers: Launchers

- These are special sequencers capable of sequentially executing other sequencers.
- They can be behaviorally configured through a project via a bit-mask.
- Operators can configure them to potentially exclude unnecessary steps based on the usage context.
- They are versatile and can be modified over time for implementing new hardware or making changes to machine usage procedures.

# Launcher example:

## Recover Storage Ring after Beam Dump

- Initially drafted based on paper-based procedures for operations to be carried out on Elettra following a Beam Dump.
- Performs the necessary actions and checks until the first injection into SR, which is still done manually for safety reasons.
- Enables a reduction in preparation times compared to manual execution using specific GUIs.
- Eliminates human errors of forgetting actions or checks.
- In many cases, it can be executed while concurrently addressing faults that led to the Beam Dump, thereby saving additional time.
- Continuously evolving and improving.

# Recover Storage Ring after Beam Dump: the operations:

Device	Description
seq/recover/beamdump s	Recover SR after BD
seq/check/zerocurrmb s	check sr current is Zero
sr/diagnostics/dcct s4	
seq/check/rf s2	Check RF2 OK
seq/check/rf s3	Check RF3 OK
seq/check/rf s8	Check RF8 OK
seq/check/rf s9	Check RF9 OK
seq/off/ramp b	Switch Booster Injection OFF
seq/check/mod p	P active MOD check and right MIMO optimizers chooser
seq/check/scw	Check SCW ON
seq/check/3hc	Check 3HC state
seq/check/ps booster	Check current and state of BOOSTER power supplies
seq/off/tunefb	Switch off Tune Feedback
seq/off/meanfb	Switch OFF Mean Feedback
seq/off/sdo	Put OFF SDO
seq/disable/launch id s	Disable ID launcher with retry
seq/open/launch id s	Open ID launcher with retry
seq/recover/ps s	Recover PS SR
seq/close/launch frtnd eh	Close User's Frontend launcher with retry
seq/open/bst bts	Open Beam Stoppers BTS
seq/on/ramp b	Switch Booster Injection ON & ramp Booster RF and PS
seq/set/master oscillator s	Set Master Oscillator to nominal freq, energy dependant

# Recover Storage Ring after Beam Dump: the on-field show

Video of the sequence in action, captured on-site on May 14, 2021, following a Beam Dump in “Light for Users” operations.

**SPOILER:** It won't be able to complete all the steps.

The Beam Dump had been caused by the shutdown of an entire vacuum rack that serves sections 2 and 3 (and partly 1), which had not yet been resolved.

Due to the active safety interlock, it won't be able to open the BSTs (Beam Stoppers) of the BTS (Booster to Storage ring transfer line)



Sequencer - tom:20000 - GeneralList

GeneralList Recover SR after BD [Start] [Stop] [Clear] [Log]

Tree View Node View **Recover SR after BD**

Device	State	Enable	Block	Executed	Last Exec	Elapsed	Description
seq/recover/beamdump s	FAULT	<input checked="" type="checkbox"/>			0d 23h 31m	278	Recover SR after ...
seq/check/zerocurrmb s	OFF	<input checked="" type="checkbox"/>	YES	YES	5d 8h 35m	1	check sr current i...
seq/check/rf s2	OFF	<input checked="" type="checkbox"/>	NO	YES	5d 8h 35m	0	Check RF2 OK
seq/check/rf s3	OFF	<input checked="" type="checkbox"/>	NO	YES	5d 8h 35m	0	Check RF3 OK
seq/check/rf s8	OFF	<input checked="" type="checkbox"/>	NO	YES	-	2	Check RF8 OK
seq/check/rf s9	FAULT	<input checked="" type="checkbox"/>	NO	NO	0d 23h 36m	6	Check RF9 OK
seq/off/ramp b	OFF	<input checked="" type="checkbox"/>	NO	YES	5d 8h 35m	6	Switch Booster Inj...
seq/check/mod p	OFF	<input checked="" type="checkbox"/>	NO	YES	-	0	P active MOD che...
seq/check/scw	FAULT	<input checked="" type="checkbox"/>	NO	NO	1d 12h 46m	1	Check SCW ON
seq/check/3hc	OFF	<input checked="" type="checkbox"/>	NO	YES	5d 8h 35m	0	Check 3HC state
seq/check/ps booster	OFF	<input checked="" type="checkbox"/>	NO	YES	-	5	Check current an...
seq/off/tunefb	OFF	<input type="checkbox"/>	YES	NO	-	0	Switch off Tune F...
seq/off/meanfb	OFF	<input type="checkbox"/>	NO	NO	1d 4h 30m	0	Switch off Mean ...
seq/off/sdo	OFF	<input checked="" type="checkbox"/>	NO	YES	5d 7h 35m	0	Put OFF SDO
seq/disable/launch id s	OFF	<input checked="" type="checkbox"/>	YES	YES	5d 8h 35m	3	Disable ID launch...
seq/open/launch id s	OFF	<input checked="" type="checkbox"/>	YES	YES	5d 8h 35m	5	Open ID launcher ...
seq/recover/ps s	OFF	<input checked="" type="checkbox"/>	YES	YES	5d 8h 31m	206	Recover PS SR
seq/on cycle/ps smalls	OFF	<input checked="" type="checkbox"/>	YES	YES	-	120	Switch ON and CY...
seq/on cycle/ps bigs	OFF	<input type="checkbox"/>	YES	NO	-	153	Switch ON and CY...
seq/on cycle/ps miscs	OFF	<input type="checkbox"/>	YES	NO	5d 9h 28m	68	Switch ON and CY...
seq/restore/mf ps s	OFF	<input checked="" type="checkbox"/>	YES	YES	5d 8h 31m	77	restore MachineFile
seq/close/launch frnd eh	OFF	<input checked="" type="checkbox"/>	YES	YES	5d 8h 31m	9	Close User's Front...
seq/open/bst bts	OFF	<input checked="" type="checkbox"/>	YES	YES	5d 8h 31m	2	Open Beam Stop...
seq/on/ramp b	OFF	<input checked="" type="checkbox"/>	YES	YES	5d 7h 35m	31	Switch Booster Inj...
seq/set/master oscillator s	OFF	<input checked="" type="checkbox"/>	YES	YES	5d 8h 30m	0	Set Master Oscilla...

Refreshed a subset of 230 sources over 1248 in 5 milliseconds

psch\_s1.1

ON  Enable

LFB

ON  LFB On

OFF  Remote

Start Cycling  Ready

Abort  ---

Reset  ---

Current **4.599 [A]**

Set point **4.599 [A]**

Local Feedback ON  
Power supply ON  
REMOTE control

Show Logs

PSQ1\_S1

Normal Status bits

ON  Reset On  Off

Remote  Cycling  Abort

Show Tango Logs

Set Point **194.590 [A]**

Current **194.600 [A]**

PSQ1\_S1

State

**RUNNING**

ON

OFF

RESET

CYCLE

ABORT

Set Point: **0.060 [1]**

DEVICE ON  
Power supply is running waveform

psch\_b5.1

File View

Normal Expert Ramp Disorders

State

**RUNNING**

ON

OFF

RESET

CYCLE

ABORT

Set Point: **0.060 [1]**

DEVICE ON  
Power supply is running waveform



Grazie  
ありがとう  
Thanks

Ref.:

A Framework for High Level Machine Automation Based on Behavior Tree,  
<https://accelconf.web.cern.ch/icalepcs2021/doi/JACoW-ICALEPCS2021-WEAL02.html>

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