



## Automated beamline alignment at Elettra Xray Diffraction Beamline

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# AGENDA

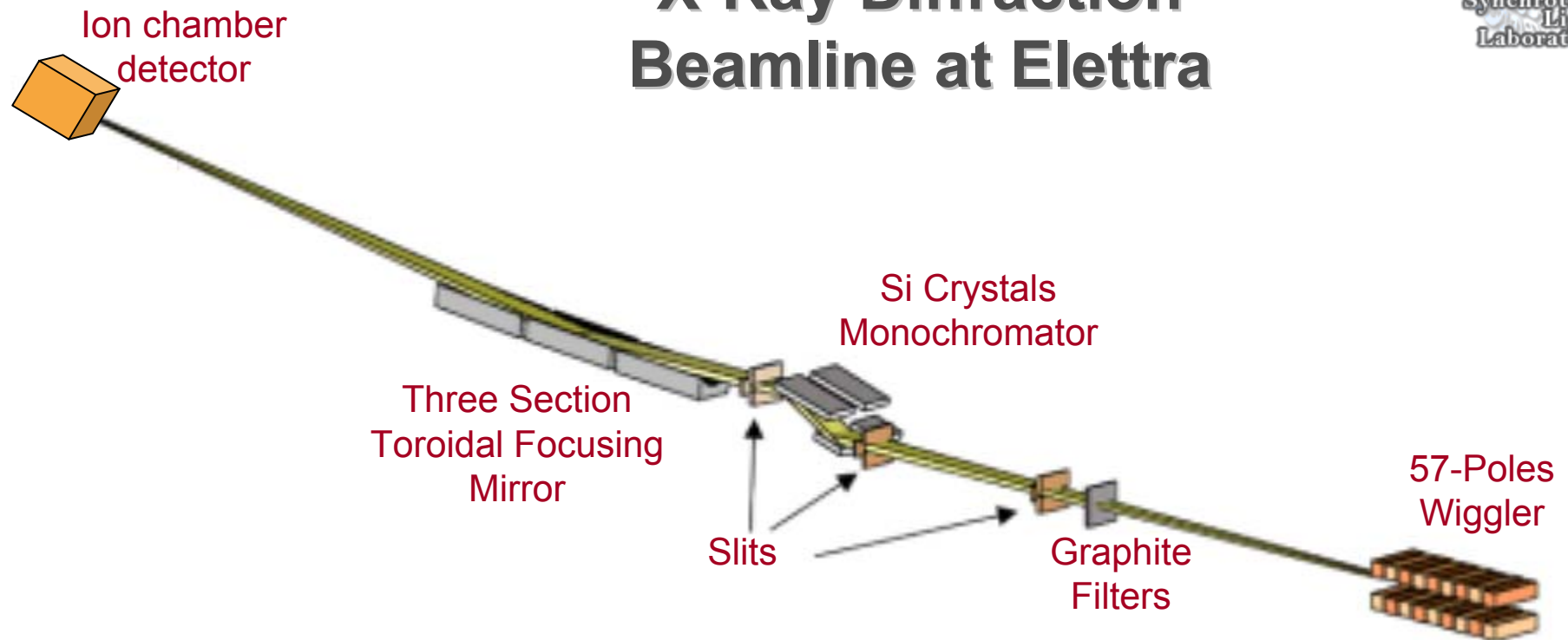


- The XRD beamline automatic alignment problem
- Applying the Teleo-Reactive Control theory
- Implementation and first results
- Future development

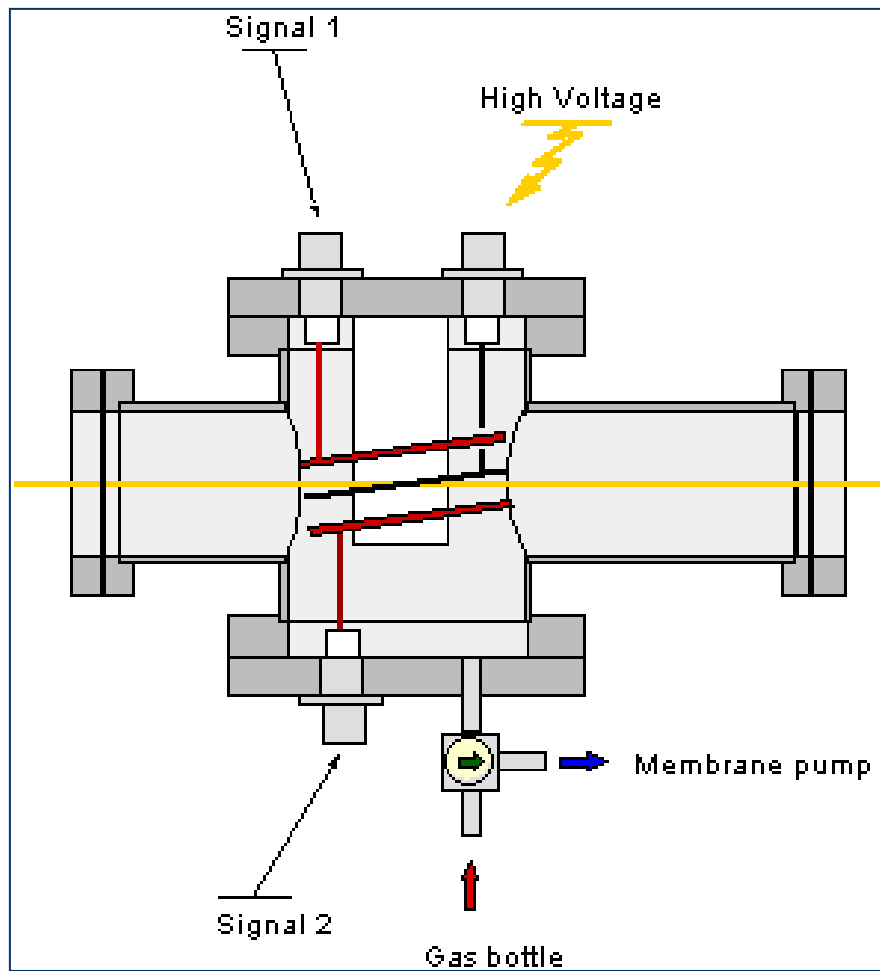
# SCENARIO



## X-Ray Diffraction Beamline at Elettra

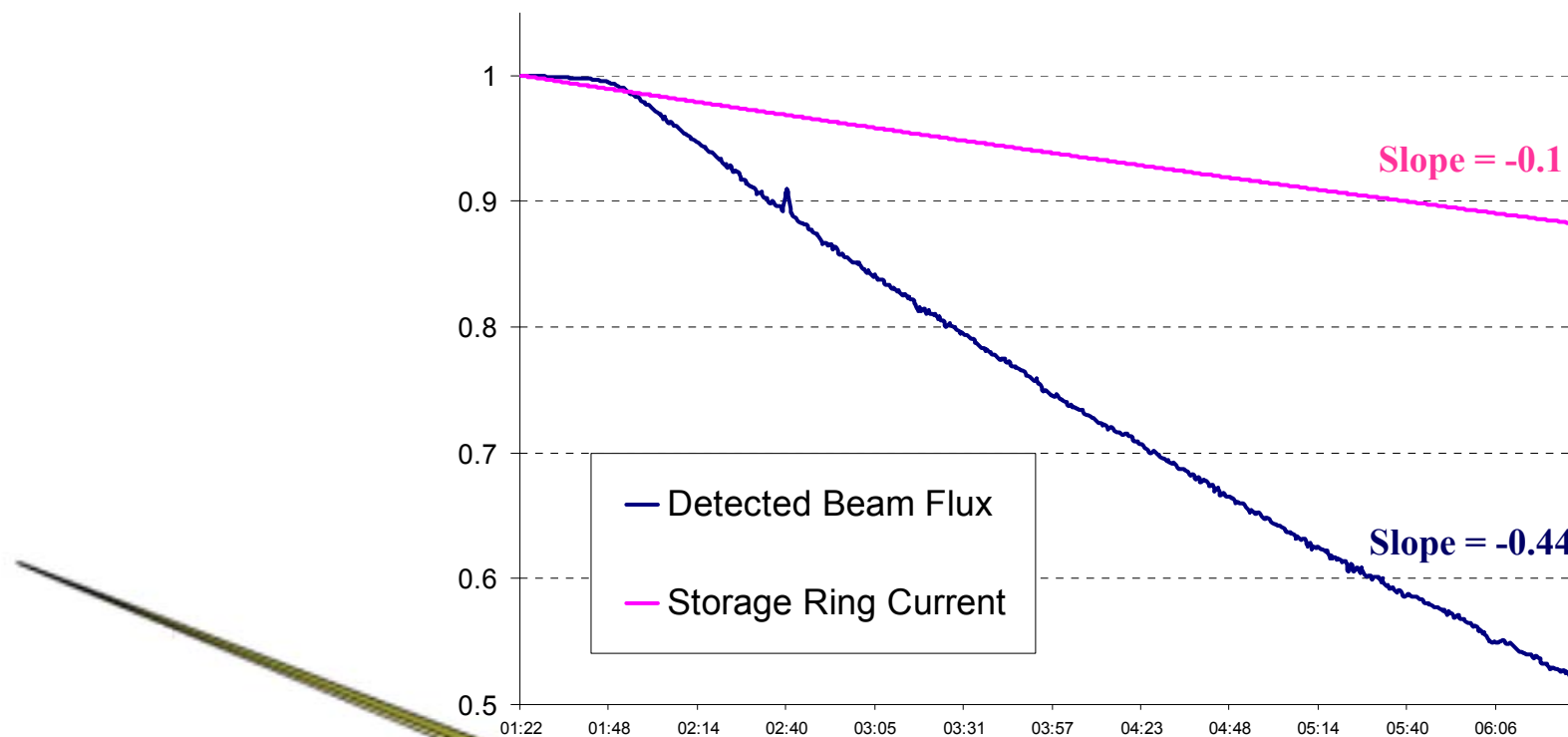


# The Ion Chamber detector



- Two ionisation chambers separated by a thin Beryllium foil
- DIFFERENCE of Signal1 and Signal2 estimates beam vertical position
- SUM of Signal1 and Signal2 estimates beam flux
- **GOAL:** maximize SUM & minimize abs( DIFF )

# Why a Feedback?



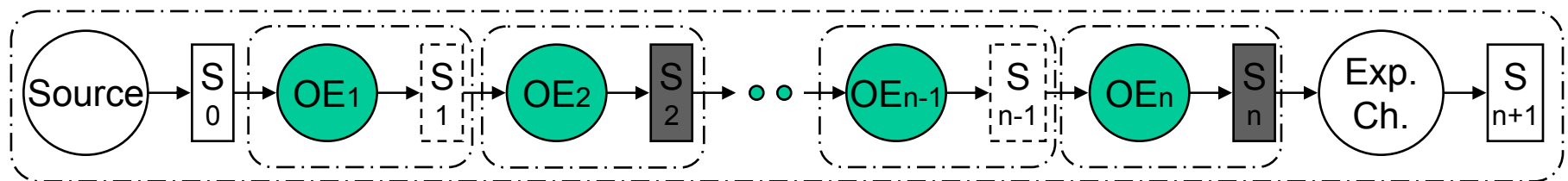
High temperature Si-Mirror deformation

Slow drifts of Storage Ring Electron Orbit

# Automatic Beamline Alignment: problem solving strategy



- Split the alignment problem into small *sub-problems* involving, for example, only one optical element and the associated sensor
- Implement for each *sub-problem* an *alignment module* using traditional or soft computing techniques
- Combine the modules using the strategic, behavioural knowledge of the optics expert



# Applying Intelligent System Concepts to the Automatic Beamline Alignment problem



- Intelligent Systems (IS) incorporate the creative, abstract and adaptive attributes of a human while minimising the undesirable aspects such as unpredictability, inconsistency, fatigue, subjectivity and temporal instability
- Hybrid Intelligent Systems integrate Knowledge Based Systems, Neural Network, Fuzzy Systems, Evolutionary Algorithms, Case-Based reasoning, Chaos Theory and traditional techniques to solve effectively complex real world problems.

# Teleo-Reactive (TR) control



- TR control occupies a region between feedback control and discrete action planning:
  - actions can be either discrete or continuous
  - actions are not guaranteed to achieve their goals
  - actions can be interrupted in response to changes in the environment
- TR plans can be represented as a sequence of condition-action pairs called TR operators.
  - TR plan execution is adaptive and opportunistic: conditions are evaluated from top to bottom and the action associated to the first true condition is performed.

$C_0 \rightarrow A_0$

$C_1 \rightarrow A_1$



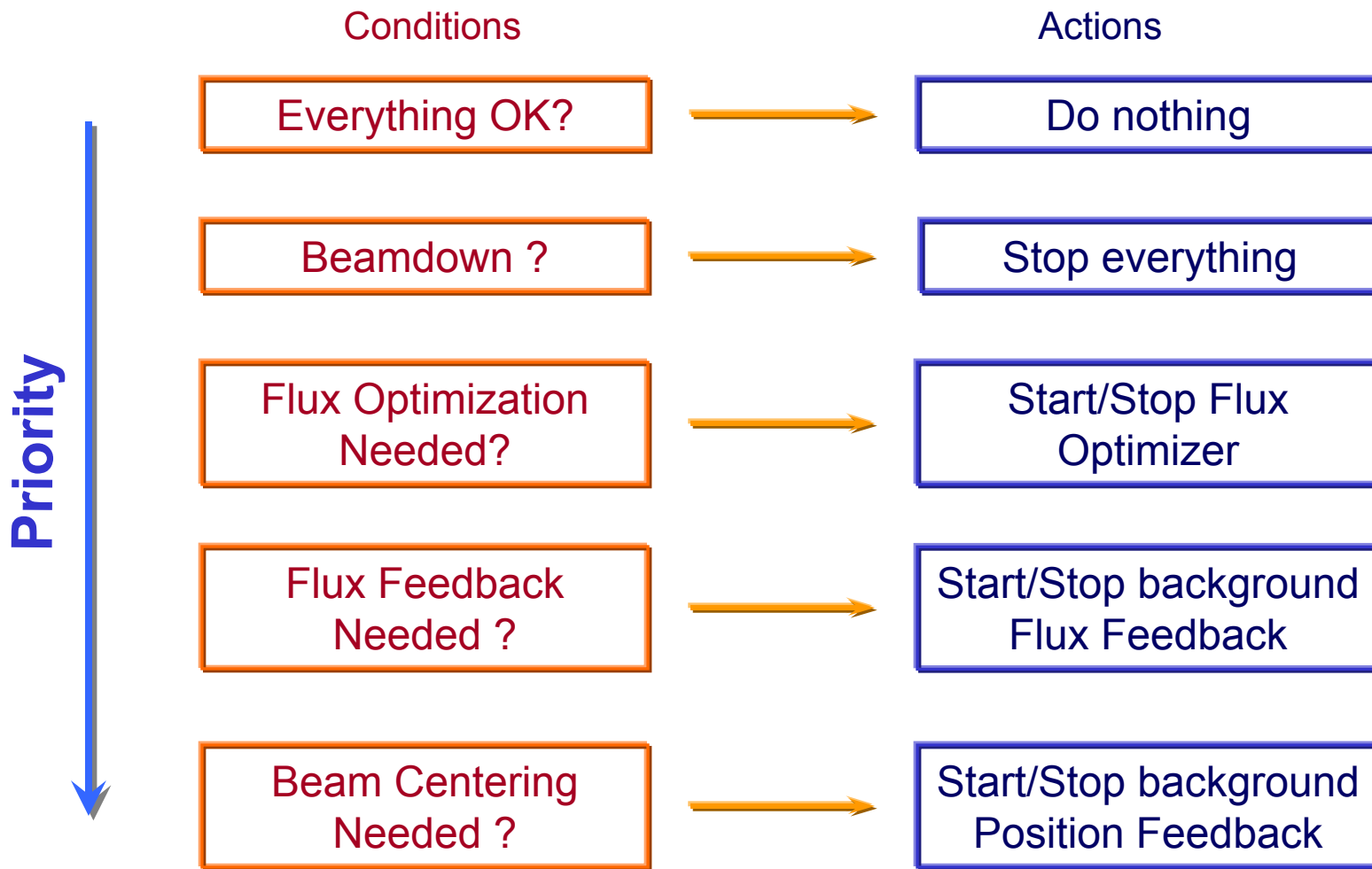
$C_i \rightarrow A_i$



$C_n \rightarrow A_n$



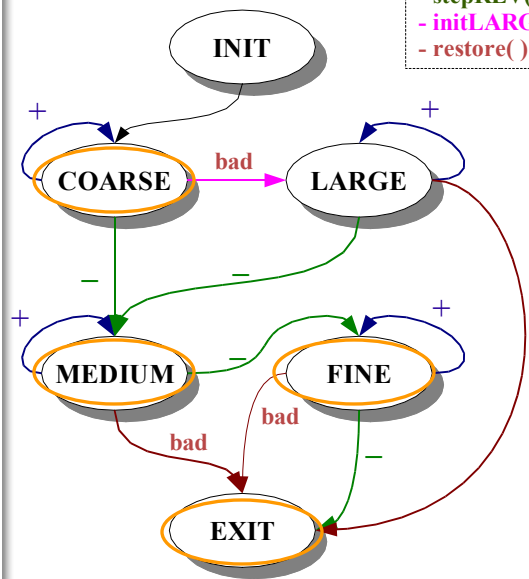
# TR control plan



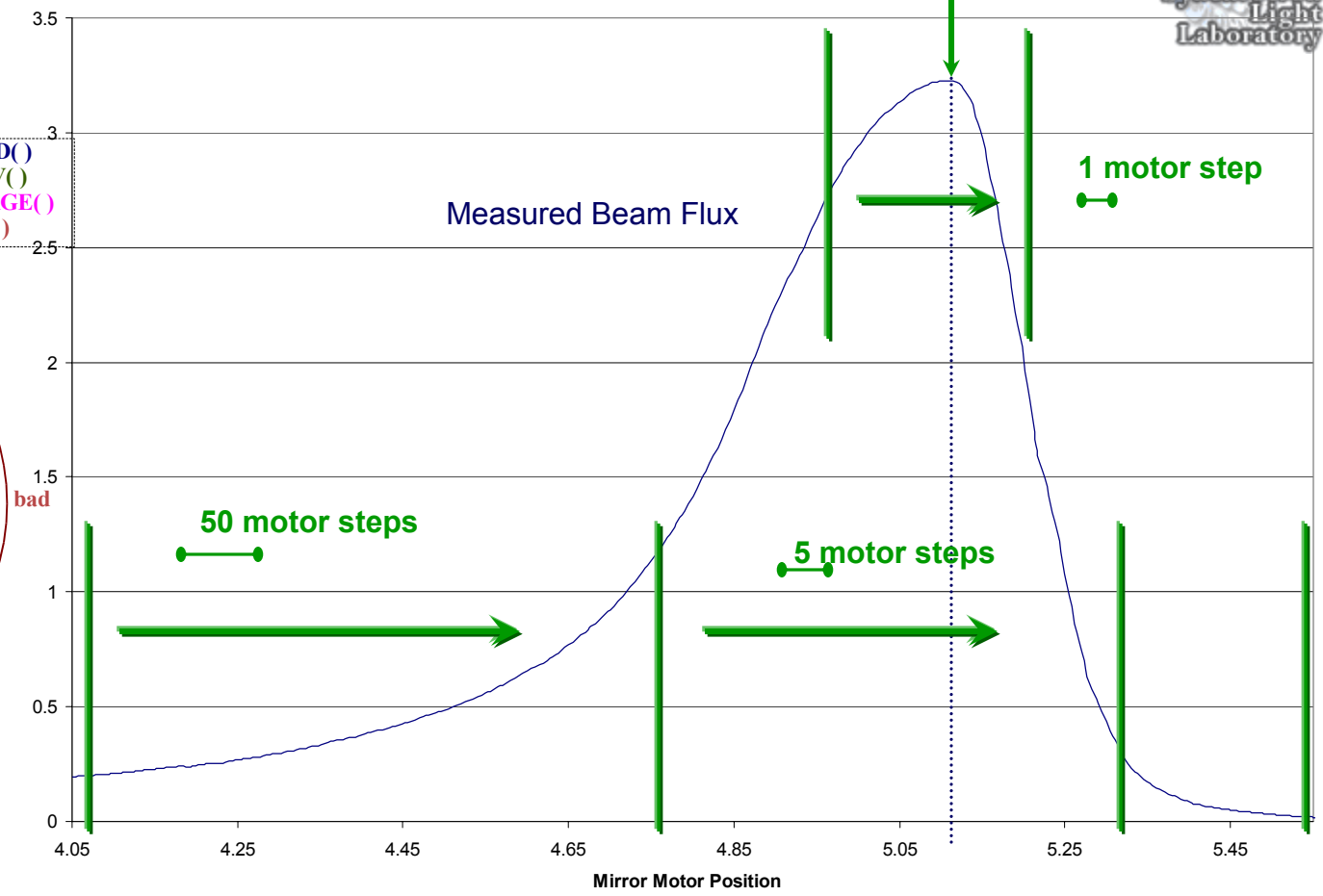
# The actions: Off-line Flux Optimizer



2° - ~~COARSE STEP~~ search with a negative slope



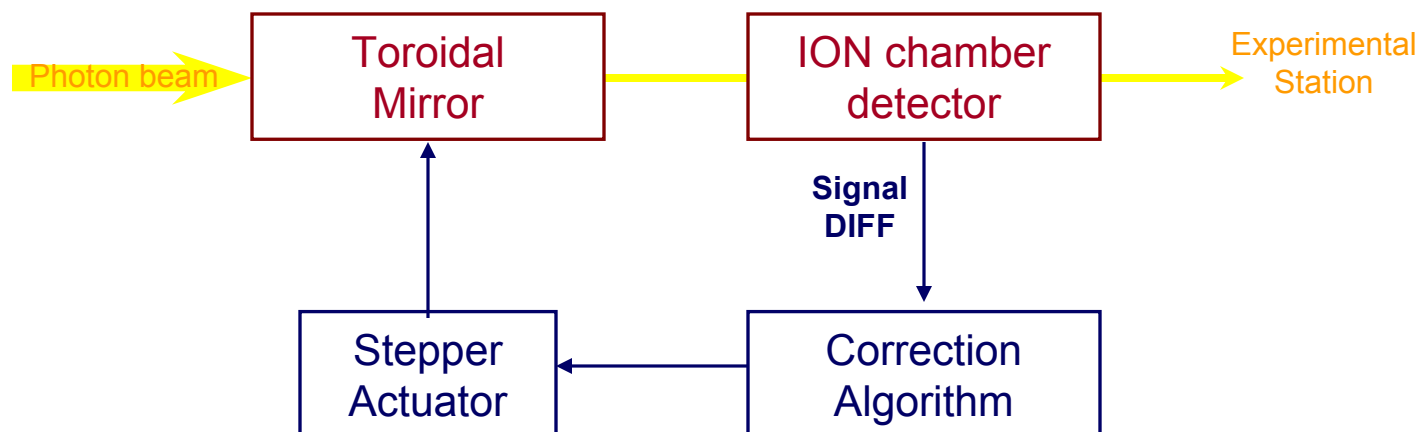
- stepFWD()
- stepREV()
- initLARGE()
- restore()



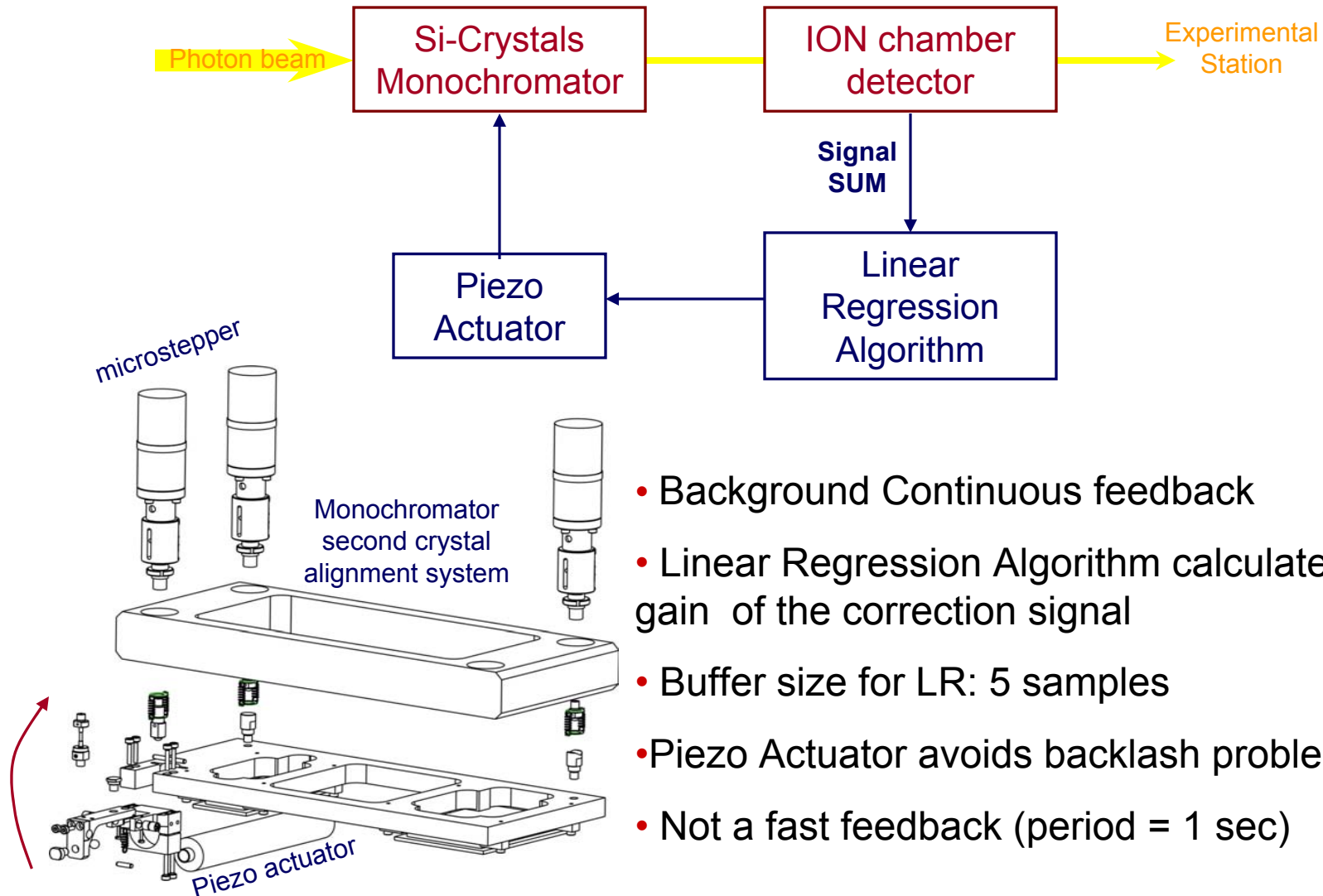
# The actions: Position Feedback



- Background Continuous feedback minimize  $\text{abs}(\text{DIFF})$
- Correction Algorithm is not enabled if  $\text{DIFF} < \text{threshold}$
- Backlash recovery procedure for Stepper Actuator
- Not a fast feedback (period = 2 sec)

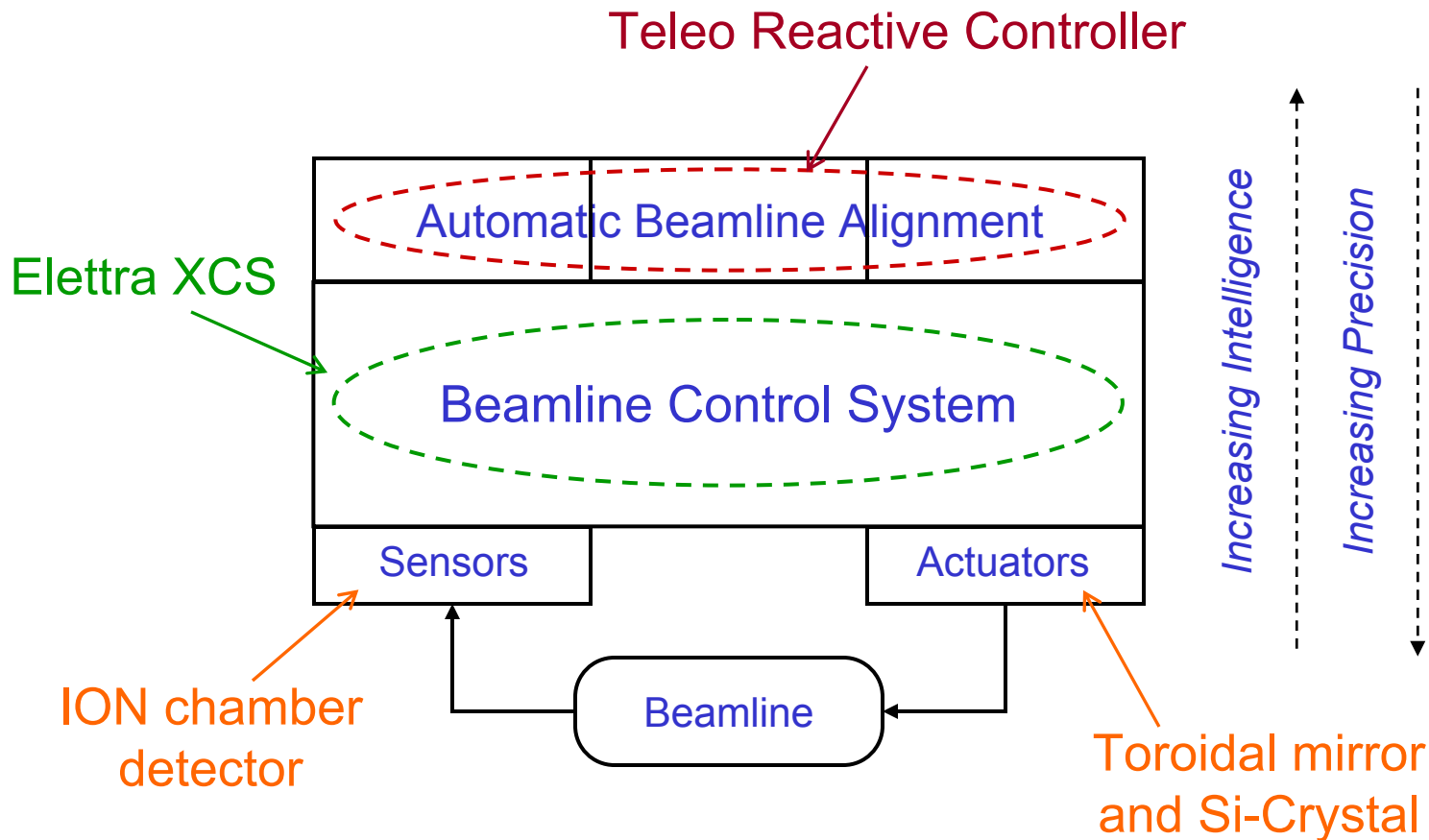


# The actions: Flux Feedback

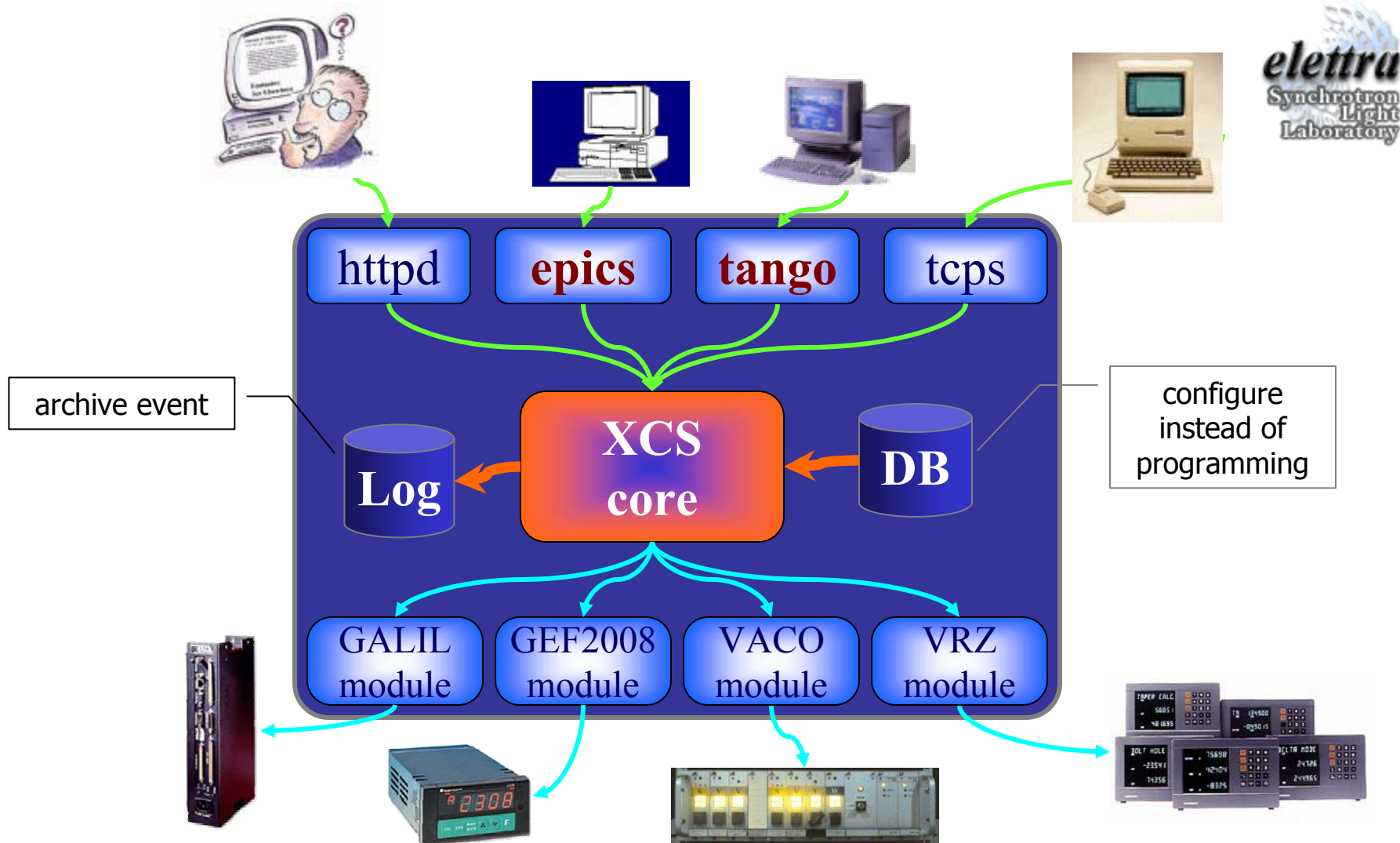


- Background Continuous feedback
- Linear Regression Algorithm calculates sign and gain of the correction signal
- Buffer size for LR: 5 samples
- Piezo Actuator avoids backlash problems
- Not a fast feedback (period = 1 sec)

# Applying the Model Reference architecture to beamline



# XCS : Elettra beamline control system



# XCS python libraries



- **pyXCS**: Very easy access to XCS
- **pyFSM**: Finite State Machine library
- **pyTRC**: Teleo Reactive Control library

A screenshot of a Windows command prompt window. The title bar reads "C:\WINNT\System32\cmd.exe". The command prompt shows the execution of a Python script: "D:\users\bille\blcs\python\pyElettra>python small.py". The output of the script is "Accumulated current = 0.0044 mA". The prompt then shows "tra>\_" on the next line.

```
C:\WINNT\System32\cmd.exe
D:\users\bille\blcs\python\pyElettra>python small.py
Accumulated current = 0.0044 mA
tra>_
```

```
# very small sample of use of XCS class

from pyXCS import *

x = XCS()
x.open('bcs102.elettra.trieste.it')
a = x.get('frontend_machine_machine_1_accucurr')
print 'Accumulated current =', a[0], a[1]
x.close()
```

# XRD Control Panel



74 - XRD Operations - By EESL

## XRD Operations

**Beamline Open/Close**

150.0 mm Shutter Stopper Last Valve Common Valve Photon Absorb1 Valve 0 Beam Stopper0A Valve 1 Valve 2 Valve 3 Photon Absorb2 Beam Stopper1 Beam Stopper2 Valve 4

0.79 mA FrontEnd Shutters XRD Shutters Beamline Valves BeamlineShutters

0.91 GeV OPEN CLOSE OPEN CLOSE OPEN CLOSE OPEN CLOSE

**Monochromator Settings**

Energy (KeV) 10.332 Modify

Lambda (Å) 1.2 Modify

**Beamline Status**

Experiment  Local

**LAUNCHER**

WebEVC BeamWatch

MarCCD Mar345

**Manual Monochromator Tuning**

piezo  fine  normal  coarse

↑ Signal DIFF: -0.008

↓ Signal SUM: -0.004

STEP (mm) Speed (mm/s) Position (mm) Piezo Voltage

0.00078125 0.15625 -0.00640625 5.01

**Automatic Beam Alignment**

Mirror Feedback Piezo Lockin Flux Optimizer

ON  OFF  ON  OFF

QUIT

Monochromator Control

Manual Flux Optimizer

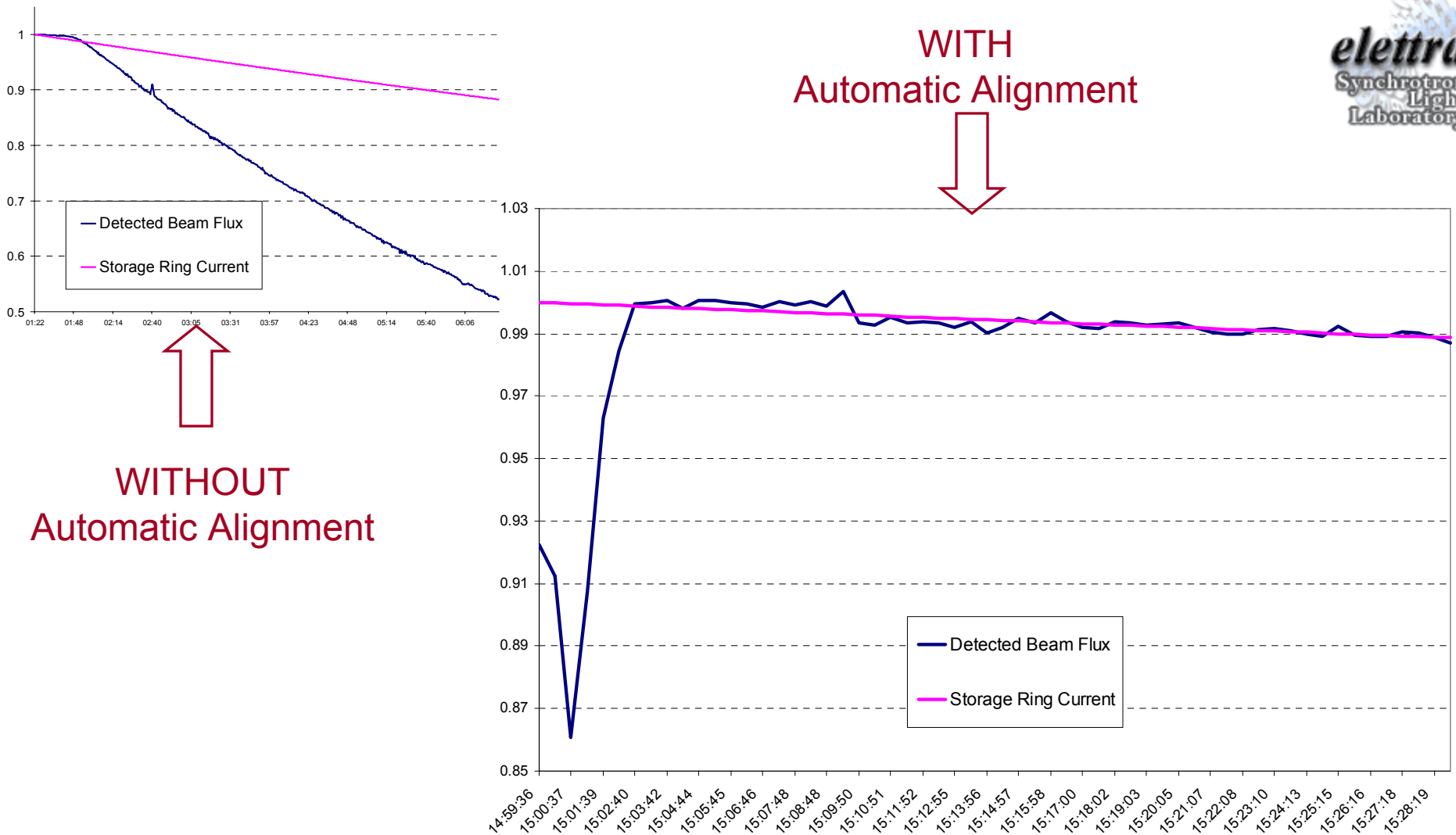
Beamline Valves Control

Tool Launcher

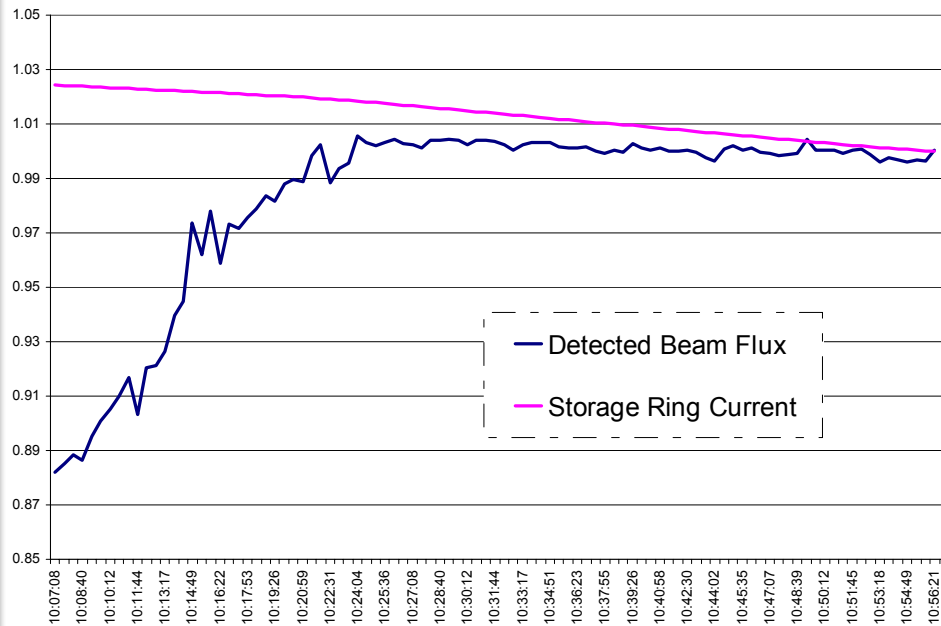
Automatic Beamline Alignment Control



# First Results

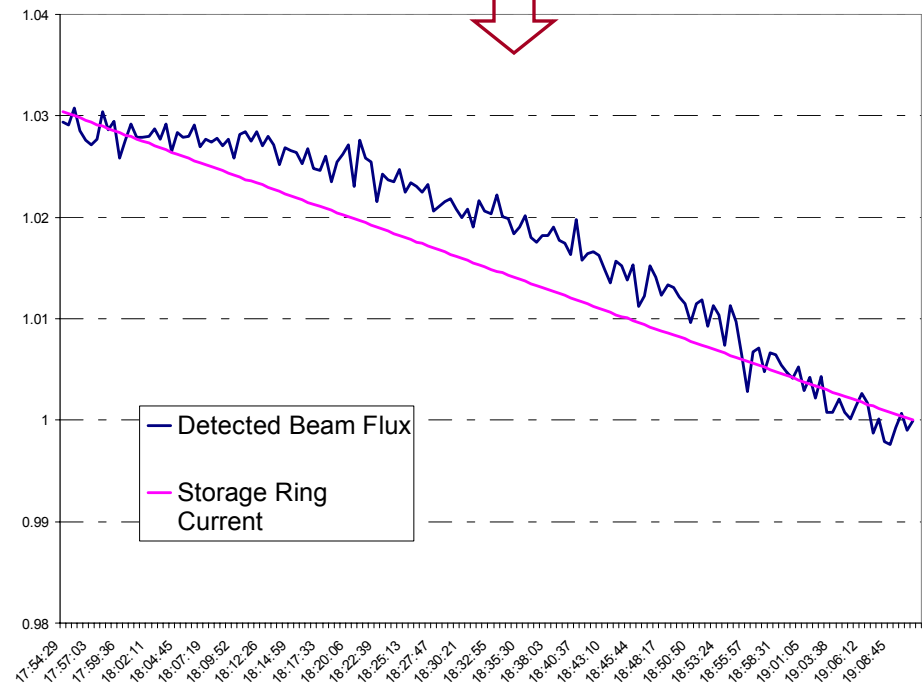


# First Results



Automatic Alignment  
"ramping"

Non Linearity due to  
mirror deformation



# Future Developments



- Refactoring of the software libraries in order to be BIOXHIT ready
- Integration with BLU-ICE
- Towards the one button beamline and EVC integration
- Integration of MarrResearch Cryogenic Sample Changer ?!?

# Acknowledgements



- Edoardo Busetto, Fulvio Bille', Kristina Djinovic, Sandy Grulja from ELETTRA
- Dorian Lamba, Alberto Cassetta from CNR