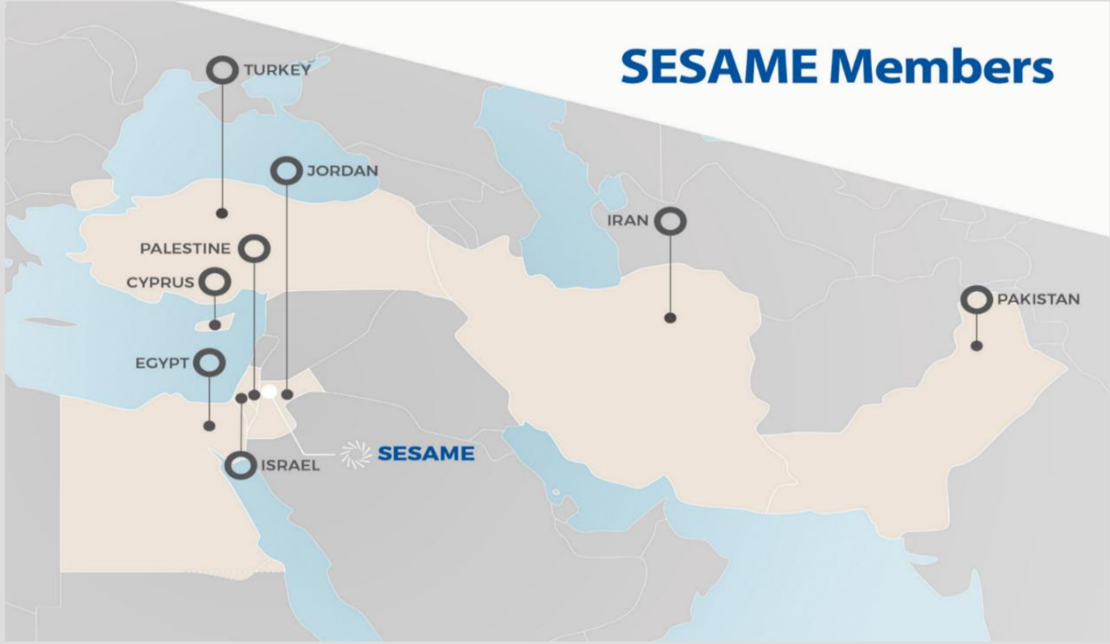
# OPERATION EXPERIENCE WITH SESAME RF SYSTEM


**Nashat Sawai on behalf of RF Team**

# SESAME Organization

- SESAME is an international organization, set up under the auspices of UNESCO.
- Located in Allan some 30km north-west of Amman, the capital of Jordan.
- The Members of SESAME are currently Jordan, Egypt ,Cyprus, Iran, Israel, Pakistan, Palestine and Turkey.




The Observers are Brazil, Canada, China, France, Germany, Greece, Italy, Japan, Kuwait, Portugal, the Russian Federation, Spain, Sweden, Switzerland, the United Kingdom and the United States of America, as well as CERN and the European Union.

# SESAME Organization

unesco

*"Building peace in the minds of men and women"*

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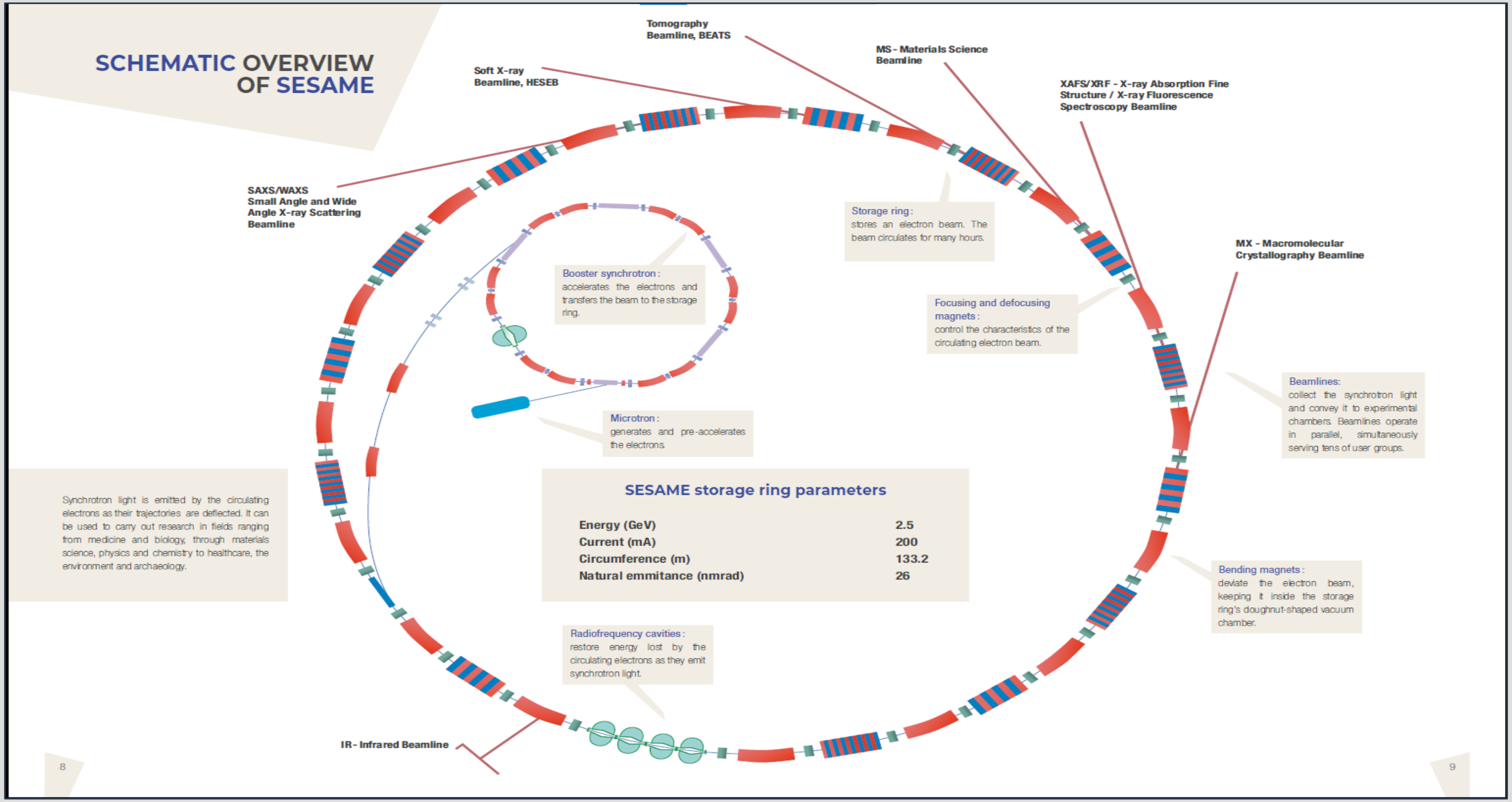
## SESAME


SESAME (Synchrotron-light for Experimental Science and Applications in the Middle East) is a third generation 2.5 GeV synchrotron-light source in Allan (Jordan) and the first major international research centre in the Middle East. it was officially opened on 16 May 2017. SESAME is an intergovernmental organization set up under the auspices of UNESCO and modelled institutionally on CERN. It is now a fully independent intergovernmental organization. UNESCO, which is the depository of the Organization's Statutes, played a vital role in getting the project started, and has provided unfailing support thereafter.

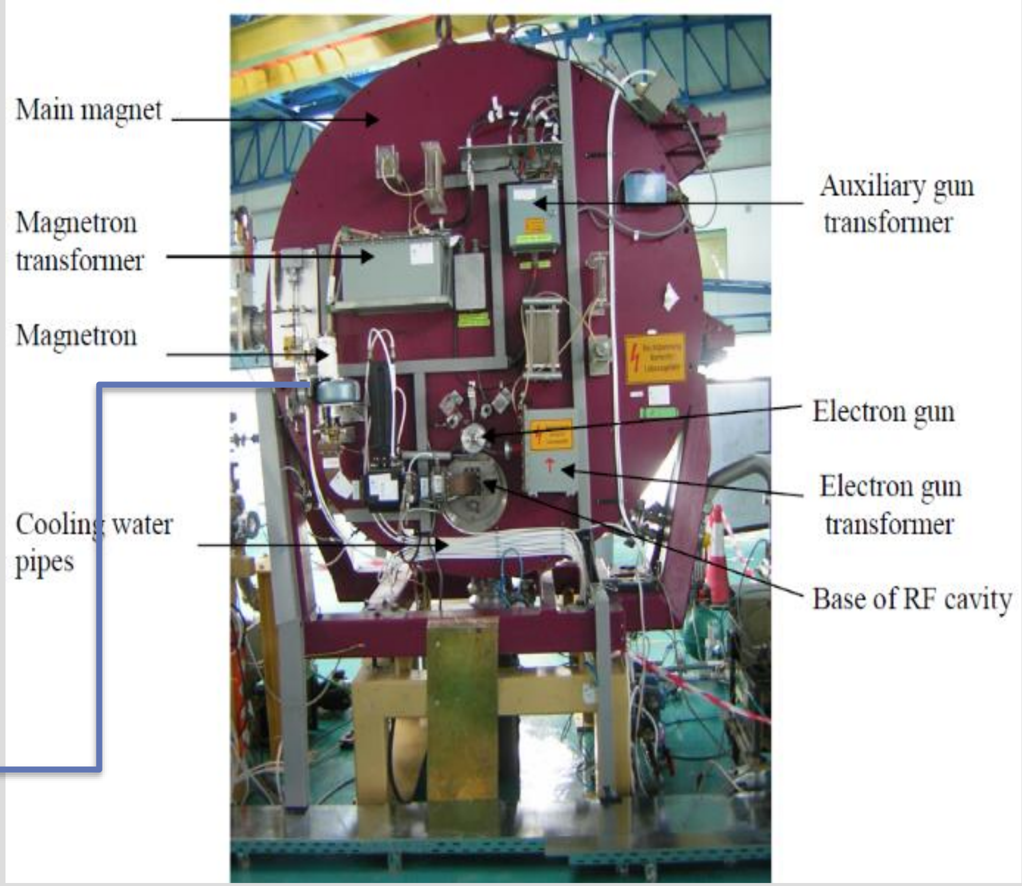
# Machine Layout



# RF SYSTEM OVERVIEW

# Injector RF System

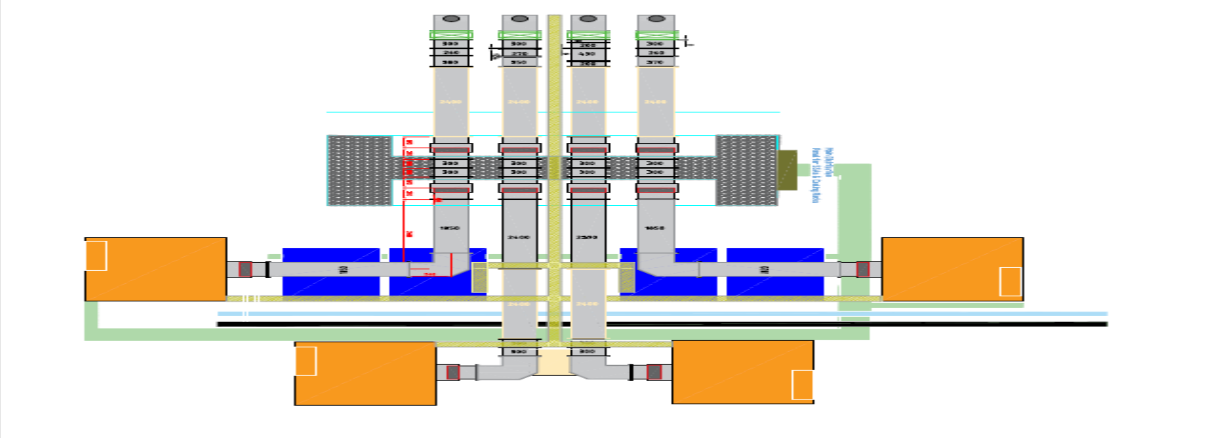
- SESAME  injector is based on BESSY I, which is 40 years old!
- Microtron 22MeV and Booster 800MeV .
- Microtron refurbishment is on-going, solid-state modulators under design by Scandinova, new Magnetron and an in-house design for the Aux.-Gun PS.
- The Booster RF system is completely refurbished; new SSA and Digital LLRF while the RF cavity still the old DORIS.
- For Future, we look forward for to swap the old Microtron with 100 MeV LINAC!




SESAME’s Microtron

# Storage Ring RF System

| Parameters | | 0.8 GeV (injection) | 2.5 GeV (User Operation) |
|---|---|---|---|
| RF/ Revolution Freq. | MHz | 499.67 / 2.25 | |
| Harmonic number | | 222 | |
| Filled buckets | | ≈198 | |
| Total RF Voltage | MV | 0.52 | 2.2 |
| Energy loss per turn | keV | 6 | 603 |
| Synchrotron Frequency | kHz | 27 | 31 |
| Energy spread | | 3.5e-4 | 11e-4 |
| Ramping time | min | 7 | |
| Bunch length | | 4.4 | 12.1 |
| Momentum compaction factor | % | 0.826 | |
| Total SSA power | | (6-12)@(0-300)mA | 320 |



# 85kW/500 MHz Solid-State Amplifiers(1)

- 4x80kW 500MHz, design by SOLEIL fabricated by SIGMAPHI-Electronics.
- 550 W per RF module, using **BLF578** transistors.
- Coaxial combiner tree,  550Wx8x10x2 - losses=80 kW
- No high voltage , No big power circulator .
- High redundancy, no trips even at maximum power with 6 faulty RF modules.

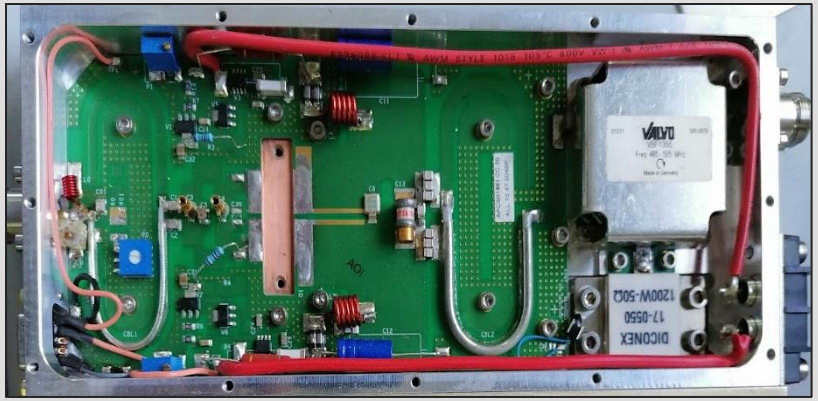
50VDC Eaton  Power supply

Inside view of 550 W RF module


Ampleon BLF578 transistor

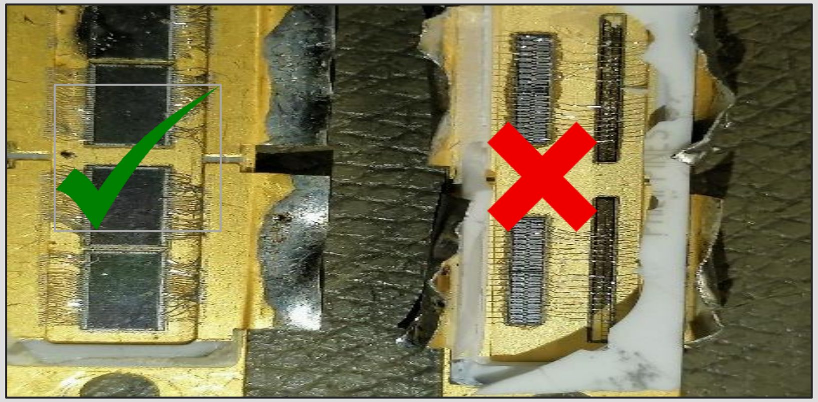
# 85kW/500 MHz Solid-State Amplifiers(2)

- Replaced 30 RF transistors till now, most of fails are due to broken transistor.
- SSAs is sensitive to overdrive, it is important to adjust the level of driving signal (LLRF or signal generator or NA) prior to operation.
- **BLF978** transistor is a successor for **BLF578**, unfortunately adapting the new transistor is not straight forward!
- Substandard" fakes transistors are being sold on the Internet.



500 W RF module of SESAME

Harvest of broken transistors BLF578



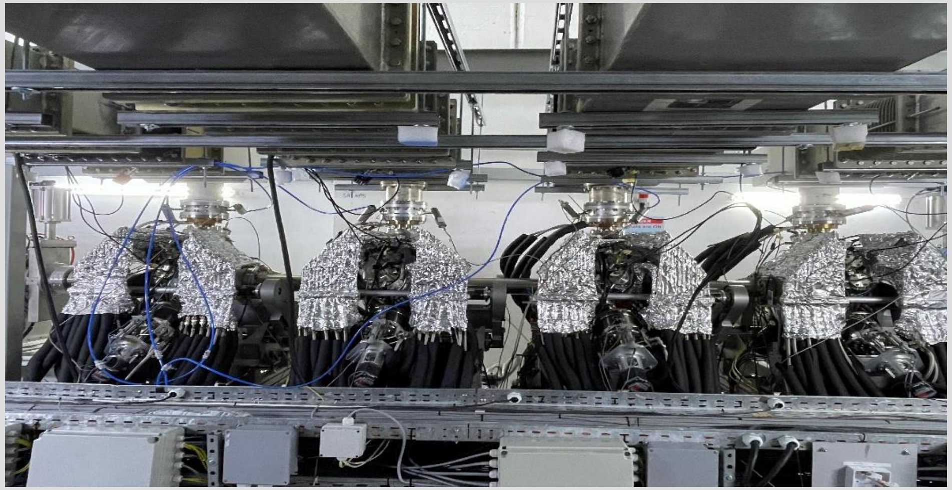
Inside view in the original and fakes transistor

# RF CAVITIES

- Four Elettra RF cavity, with gap voltage up to 630 kV .
- High Order Modes excited in the cavity are damped via means of temperature control.
- RF cavities are equipped with cooling racks to perform precise temperature control, too many HOM's are moves at once.
- Temperature of cavities set as follow (**49.7, 56, 63, 51**)Cº
- The Input coupling set 2.4 to match beamloading at higher current

Main parameters of ELETTRA RF cavity

| | |
|---|---|
| **No. of Cavities** | 4 |
| **Frequency MH** | 499.65 +/-1 |
| **Cavity Shunt Impedance MΩ** | 3.3 |
| **Quality Factor** | 43000 |
| **Coupling Factor** | 2.4 |
| **Maximum Voltage kV** | 650 |
| **Operational Voltage kV** | 430 |
| **Maximum Cavity Power kW** | 66 |
| **Maximum Forward Power kW** | 100 |



RF cavity inside storage ring

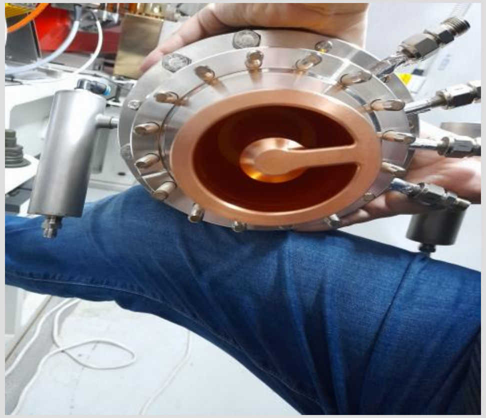
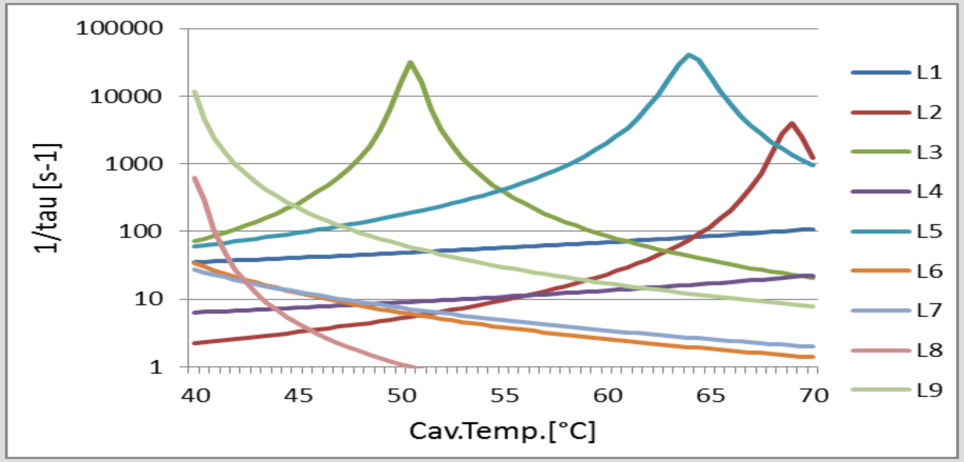


Photo for input power coupler



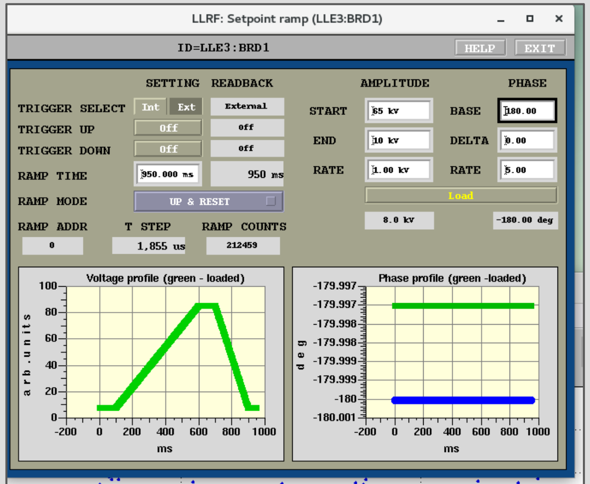

Calc. Grow rates of longitudinal CBM as a function of the cavity temp.

# Digital LLRF System

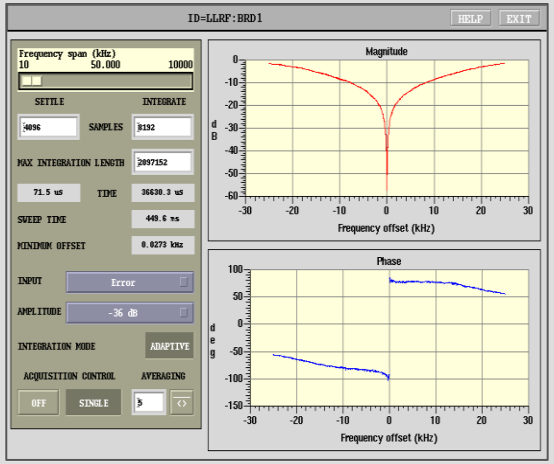
SESAME

- Commercial Digital 500 MHz LLRF system from Dimtel, also already used at ANKA,ELSA, DELTA.
- Compact Size, the Front-End, Back-End and ALO all in assembled in 2U!
- Very efficient Post-mortem with 16k samples.
- Delivered with several MATLAB tools that help in performing post-mortem analysis.

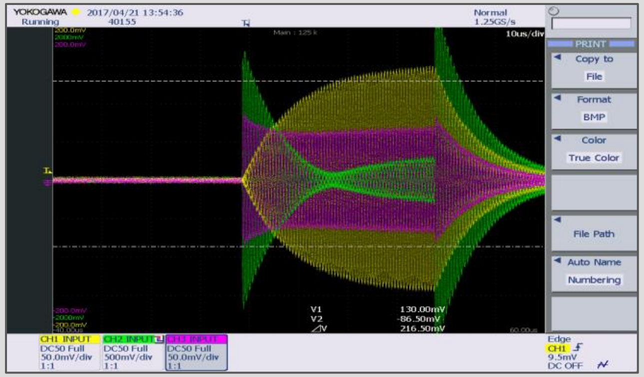

Front panel for LLRF



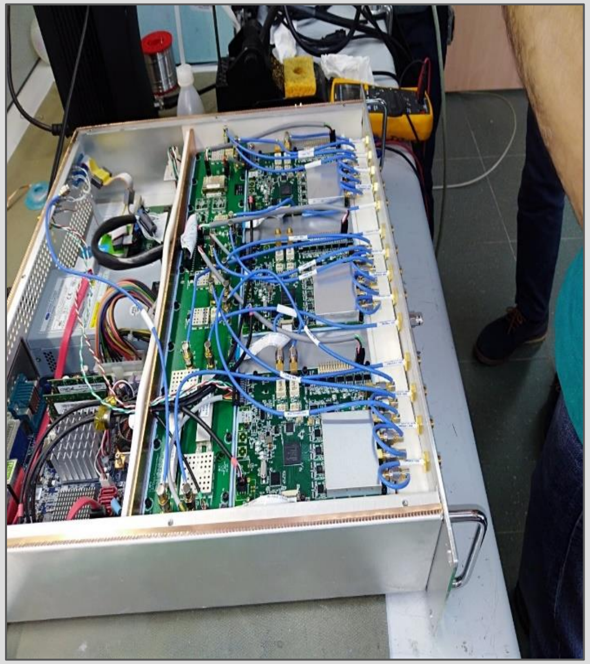

512 points arbitrary profile used for ramp RF booster with 900ms profiles.




Closed-loop disturbance rejection transfer function



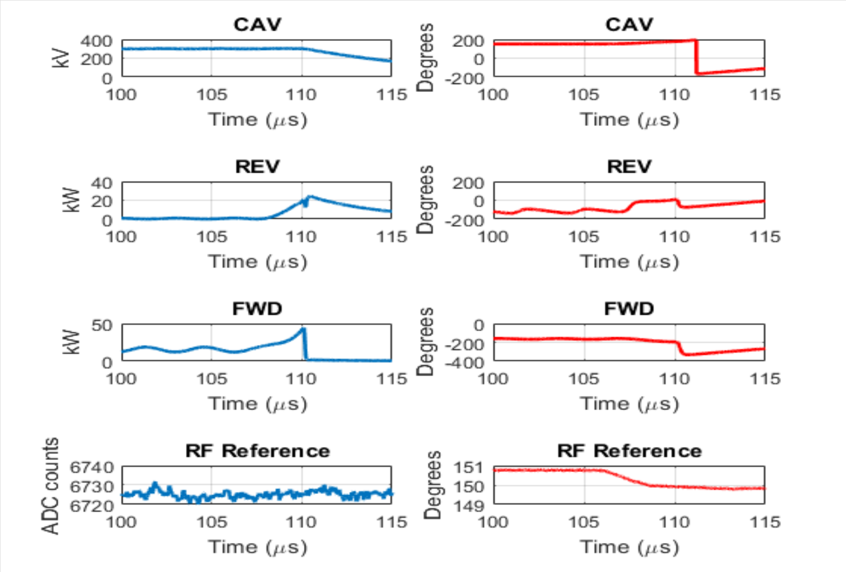

Scope trace showing incident,(pink), reverse (green), and probe (yellow) signals during conditioning. Cavity charge/discharge is clearly seen in the probe signal. With coupling β>1, reverse power is higher at the falling edge.



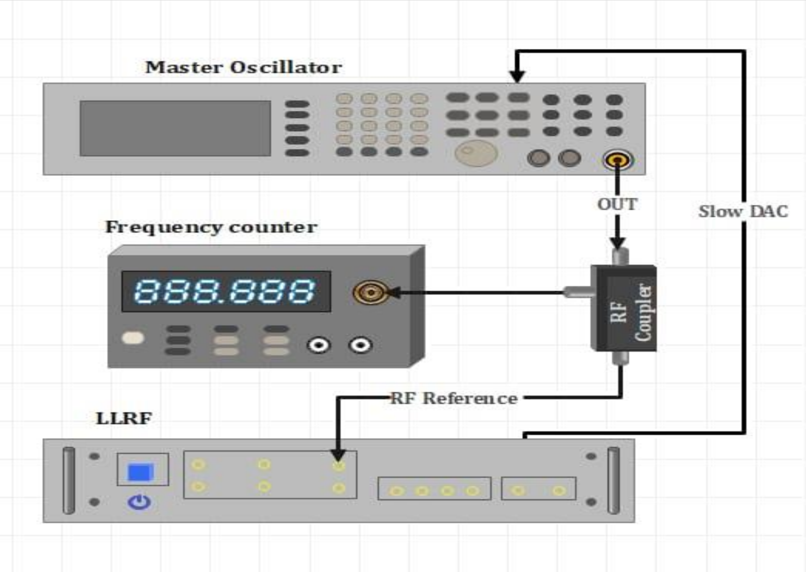
Internal view of the LLRF9

# Master Oscillator

- The old M.O performs phase discontinuity which produces RF trips .
- DC-coupled FM modulation was implemented to overcome the problem.
- The new products of signal generator of well know companies are still producing the same problem.
- Permanent solution: a new S.G model HS9001B Holzworth- and it performs phase coherent .




Post-mortem showing the old M.O (RF reference) makes phase jump




The setup to perform RF frequency adjustment via DC-coupled FM modulation input of another signal generator model (Agilent N5182A).


new M.O HS9001B from Holzworth


Old M.O (SSX-WORK Microwave) connected LLRF9 RF

# RF Operation with Beam

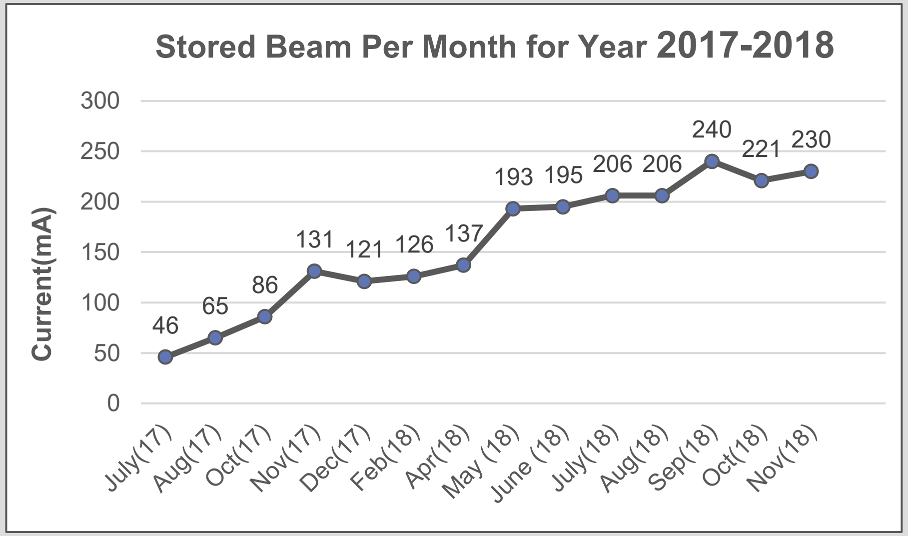
I. Store High Current in Storage Ring.

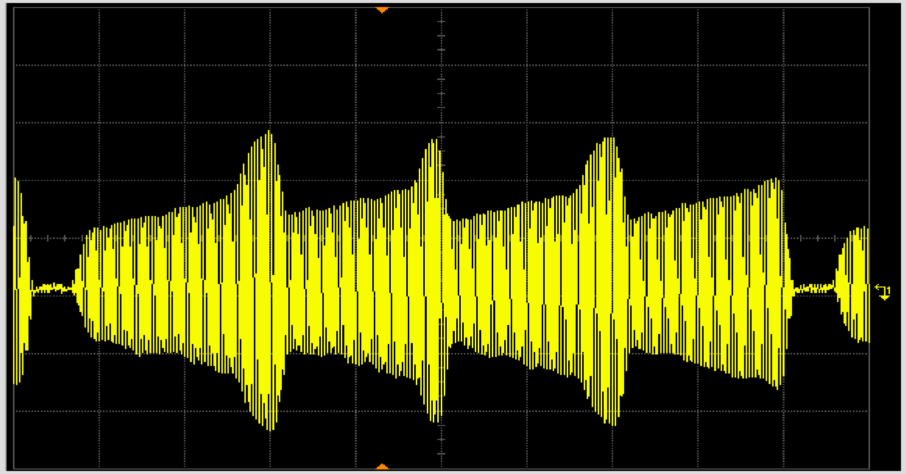
II. Coupled Bunch Instabilities.

III. Optimizing RF for Decay Mode.

# Store Higher Current in Storage Ring

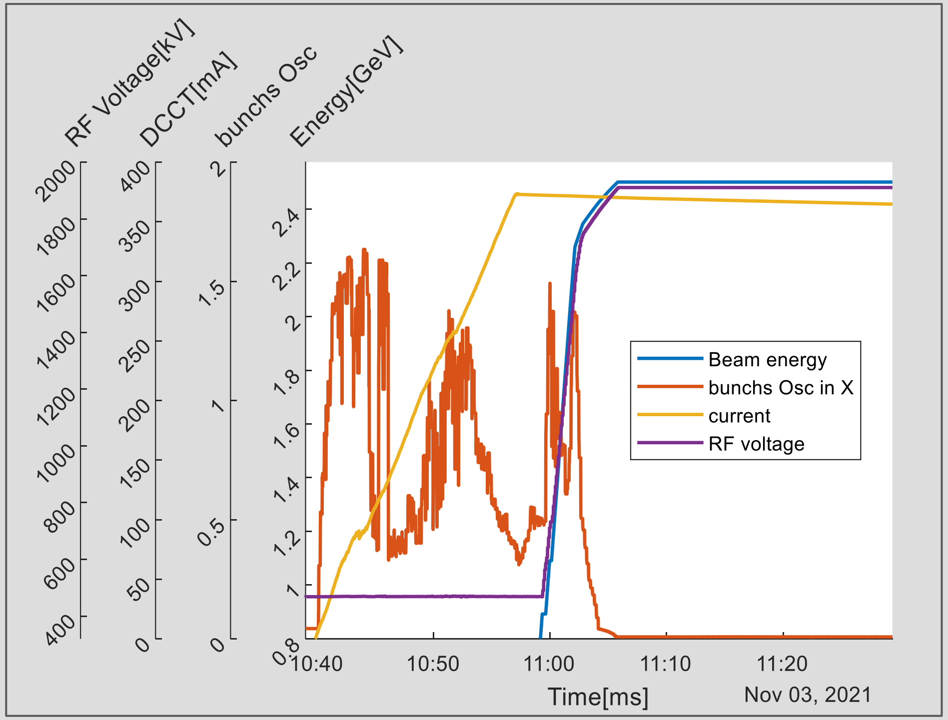
- Design current is 400 mA.
- Injection efficiency to SR gets influenced by increasing the RF voltage >180kV, cavity voltage set to 130kV to get good injection efficiency and overcome the beam loading.
- Beam-loading is considerable, cavity detuned beyond 100 kHz!.
- Optimizing the LLRF feedback loops is crucial to cope with beam loading.
- Filling the SR with 350 mA is confirmed at low energy.



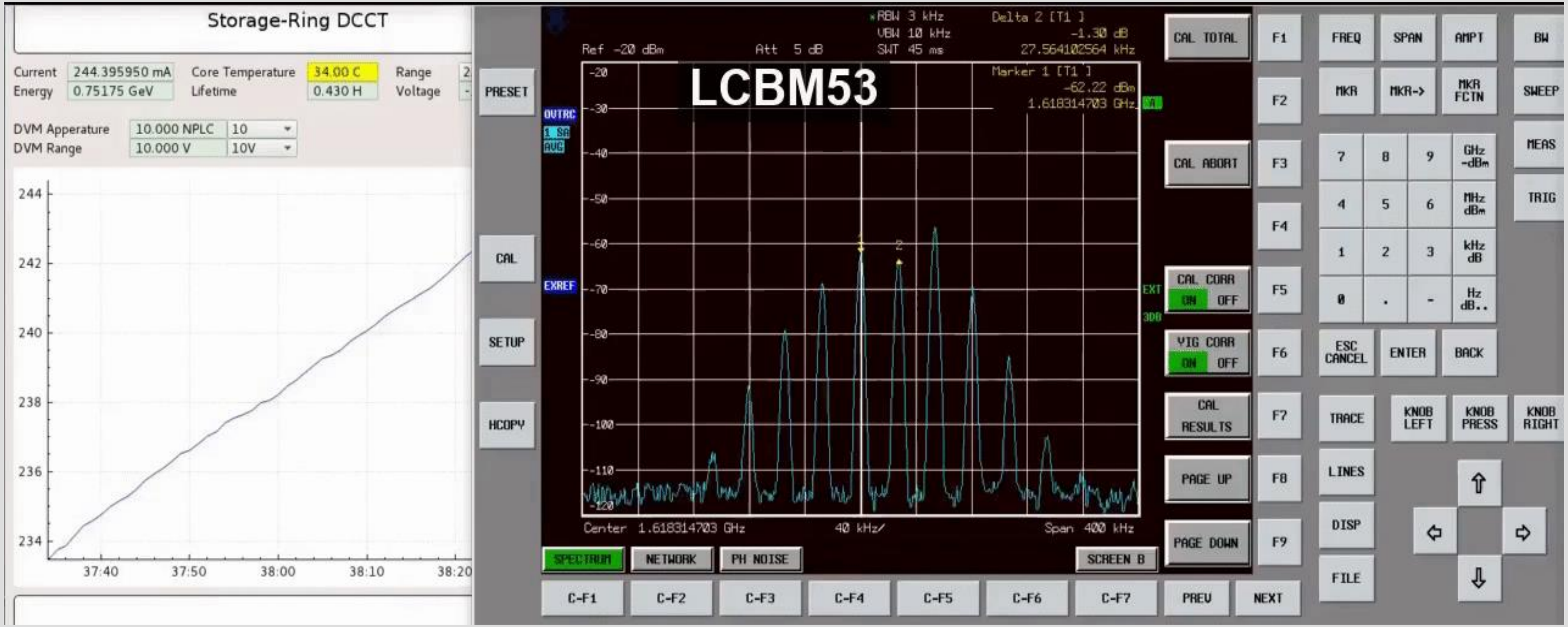
# Coupled Bunch Instabilities

- Many Long. and Tran. CBMs shows up during SR filling !
- Threshold currents for HOM instabilities are few milliamp
- At 800MeV the damping times are not quite enough to damp instabilities $\tau_x/\tau_y/\tau_z$ : 83/140/106 msec respectively .
- At low energy the beam instabilities are not destructive! filling the storage ring with 350 mA is confirmed.
- At 2.5 GeV beam performs more stability, damping times $\tau_x/\tau_y/\tau_z$ 2.7/2.3/3.7 msec respectively.



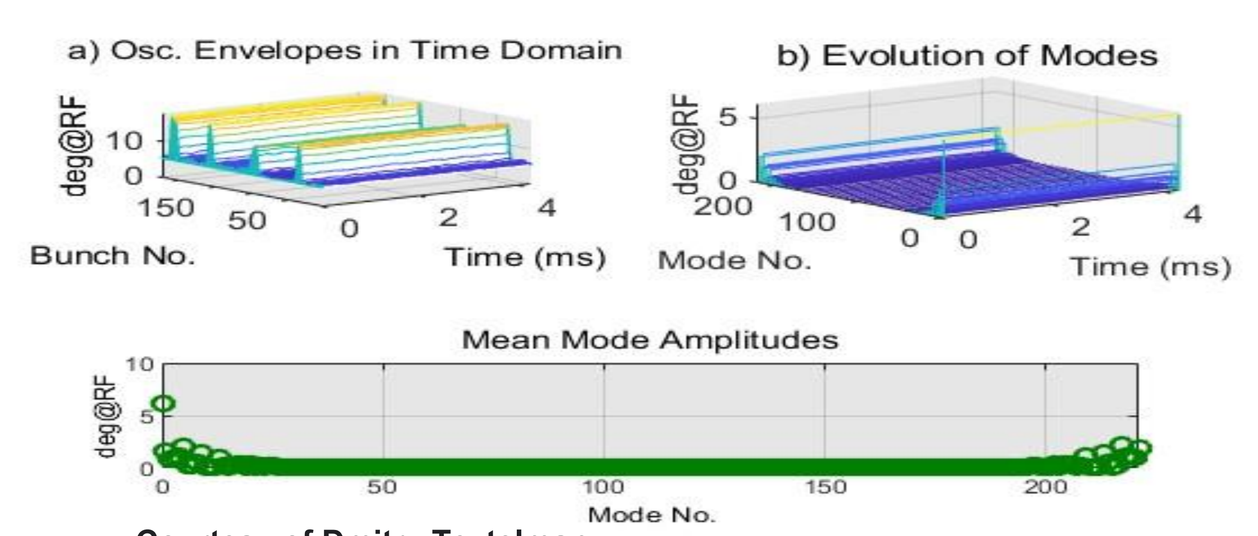
# Longitudinal Instabilities at 800 MeV

- CBM 198 (-23) is the worst driver, many synchrotron sidebands.
- The cavity temperature optimized to avoid forbidden intervals at top energy .
- After 2.48GeV; most of Long. Instabilities are suppressed.

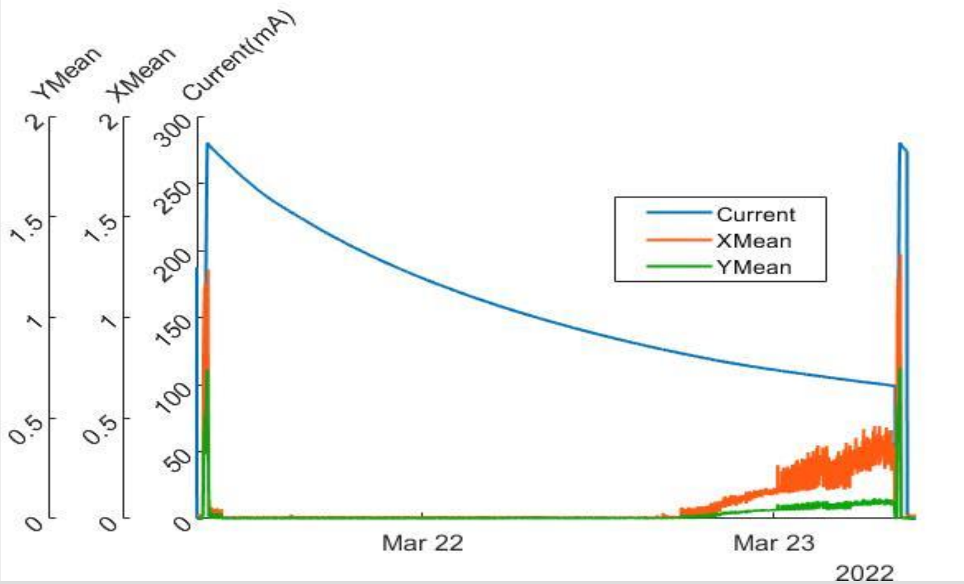


# Longitudinal Instabilities at 2.5 GeV

- Cavity detuning keeps changing while beam is decaying,
- HOM also moves and longitudinal instability raise up at low SR current <140mA.
- The driver L4 (mode 5) could easily drive low oscillation.
- Only 11 MHz shift would put it on mode 0, which will disturb operation of LLRF
- Reducing the proportional gain of LLRF Loop helps bring in stability to M0.



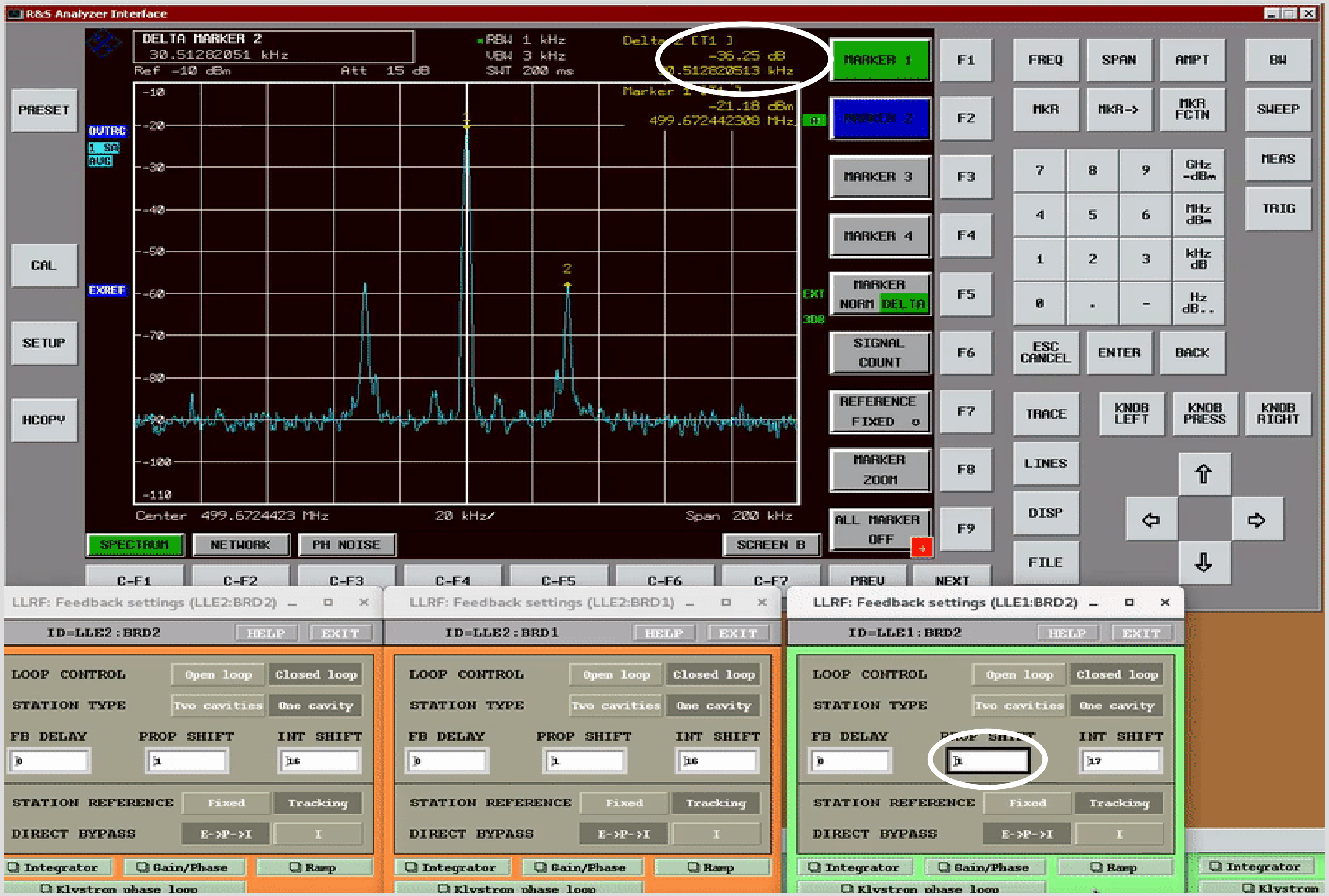

Courtesy of Dmitry Teytelman



# Longitudinal Instabilities at 2.5 GeV

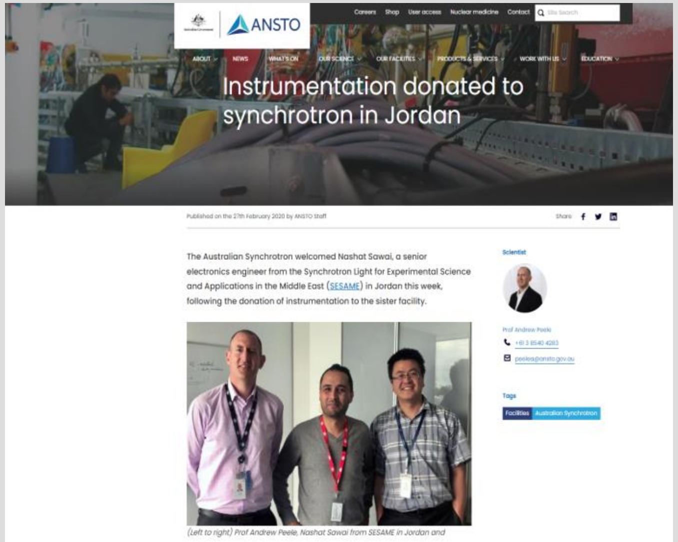
- Mode 0 get excited due to low frequency oscillation CBM 05.

- Reduce gain and the bandwidth of Feedback loop helps to get stability for Mode 0.

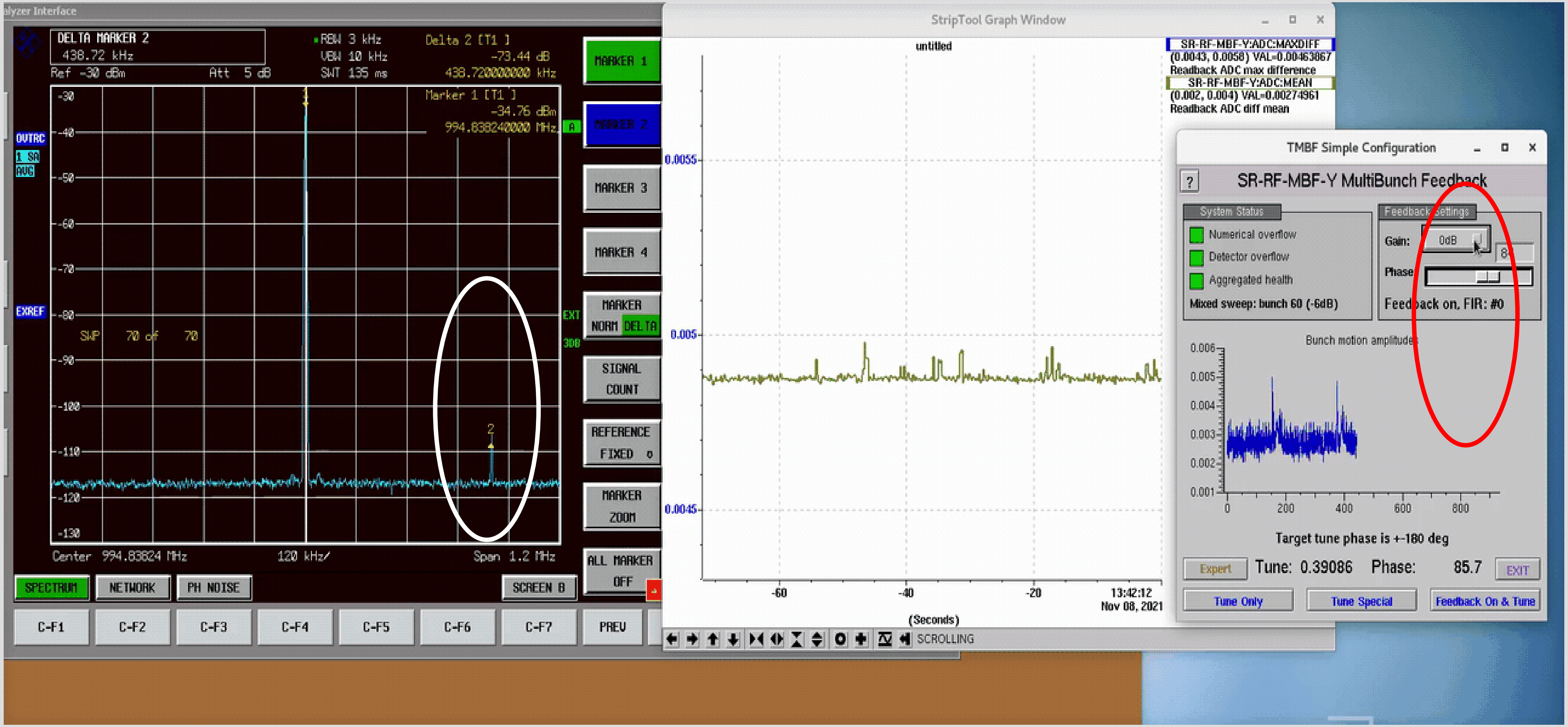


# Bunch-By-Bunch Feedback

- The collaboration that SESAME built around the globe helped in getting many donations including the Libera Bunch-By-Bunch Electronics.
- The Feedback implemented in the vertical plane had become operational, mainly used to suppress resistive wall instabilities.
- With feedback we were able to perform bunch cleaning and store single bunch
- We look forward to building the longitudinal feedback system, but still missing some necessary components; i.e; cavity kicker, back-end modulator, amplifiers !.


ANSTO
Instrumentation donated to synchrotron in Jordan
Published on the 27th February 2020 by ANSTO Staff
Share
The Australian Synchrotron welcomed Nashat Sawai, a senior electronics engineer from the Synchrotron Light for Experimental Science and Applications in the Middle East (SESAME) in Jordan this week, following the donation of instrumentation to the sister facility.
Scientist
Prof Andrew Peele
Tags
Facilities Australian Synchrotron
(Left to right) Prof Andrew Peele, Nashat Sawai from SESAME in Jordan and

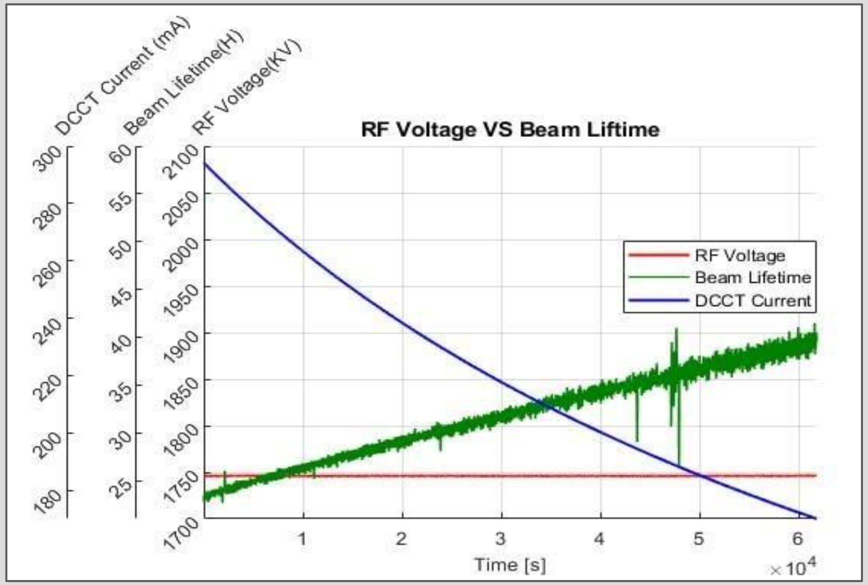
# Suppress RW instabilities Using TMBF System



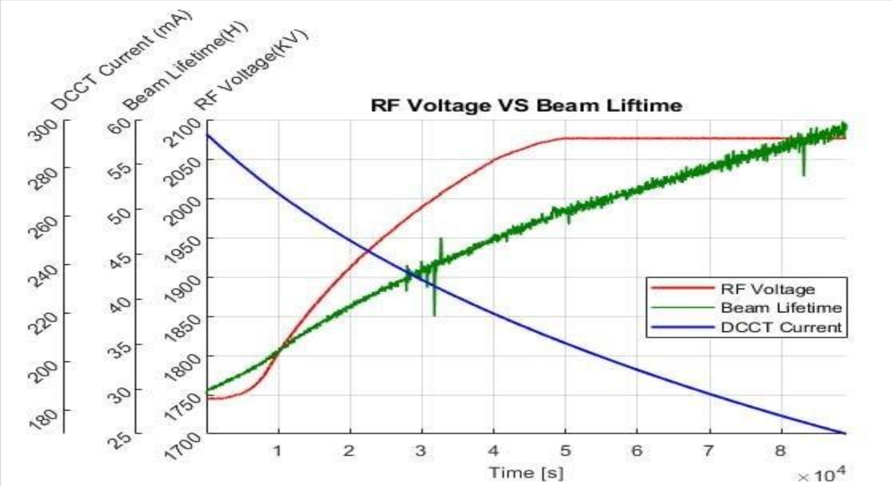
# Optimizing RF System in Decay Mode

1. As the S.R runs in the decay mode, there are needs to increase the lifetime.
2. Continuously increasing the gap voltage, while the stored beam is decaying, beam lifetime increased considerably.
3. Increasing beam lifetime will reduce the number of beam dumps and injection.

With Fixed Gap voltage




With ramped Gap voltage



# Summary

- SESAME has become a user facility with 4 beamlines.
- SESAME RF systems match the requirements of machine operation.
- Bunch-By-Bunch feedback system would allow setting the temperature of the RF cavity more freely.

# Acknowledgment

The Authors appreciate the generous donations from the

- Diamond light source.
- Australian Synchrotron.
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- Brazilian Synchrotron.

In Particular

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- Daniel Tavares (LNLS)
- Michael Abbott and Lorraine Bobb (DLS)

# Thank you for your attention

# SESAME RF Team