Karlsruher Institut für Technologie

Present Status of RF System in KARA

Akira Mochihashi on behalf of IBPT and LAS team in KIT

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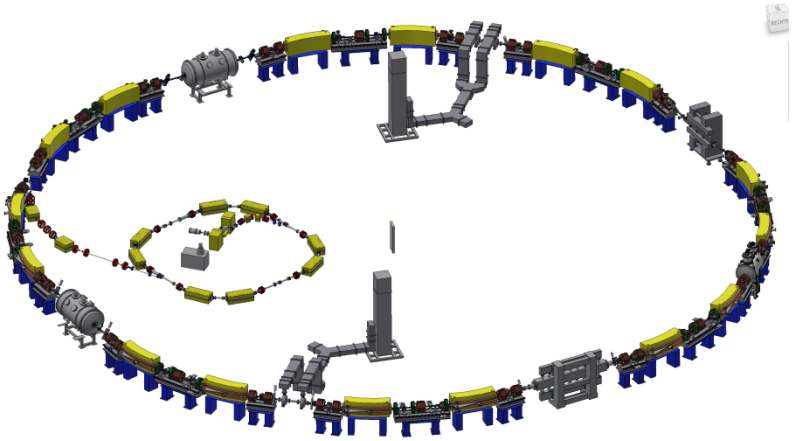
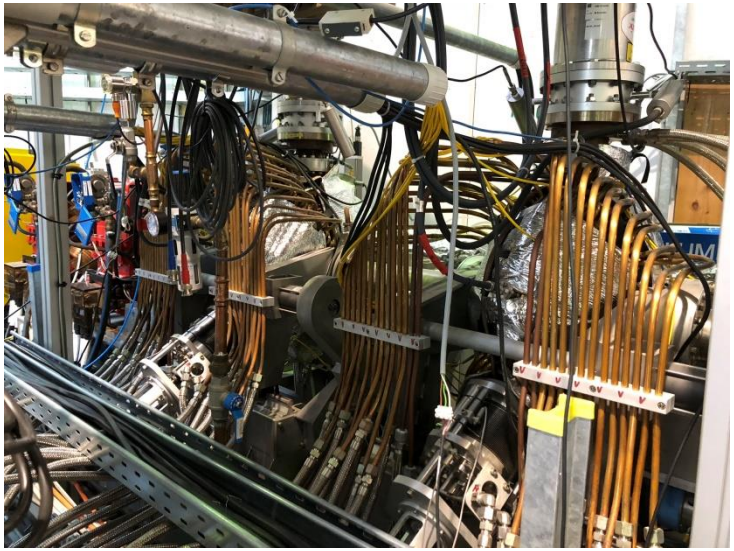
Karlsruhe Institute of Technology (KIT)





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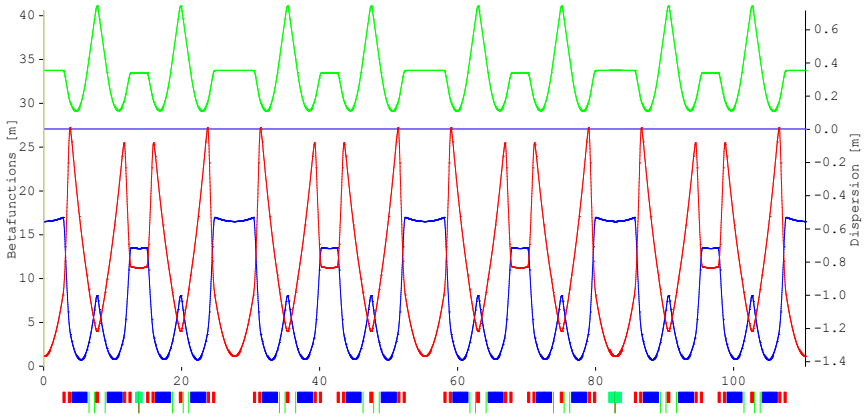
Introduction (1) Karlsruhe Research Accelerator



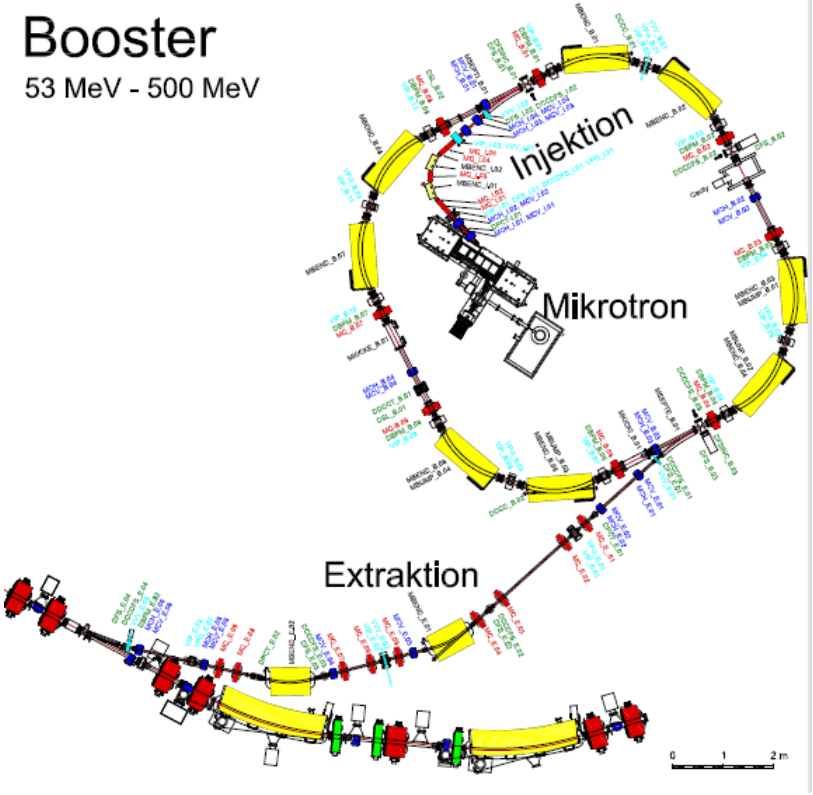
Extended DBA Lattice
(Dispersion>0 in straight section)
Designed Emittance = 59 nm-rad

Beam Energy	< 2.5 GeV
Circumference	110 m
RF Frequency	499.7 MHz
Harmonic Number	184
Number of RF Station	2
Number of Cavity in 1-Station	2
Acc. Voltage	1.4 MV (2.5 GeV)
Ring Lattice	DBA

Introduction (2) Karlsruhe Research Accelerator

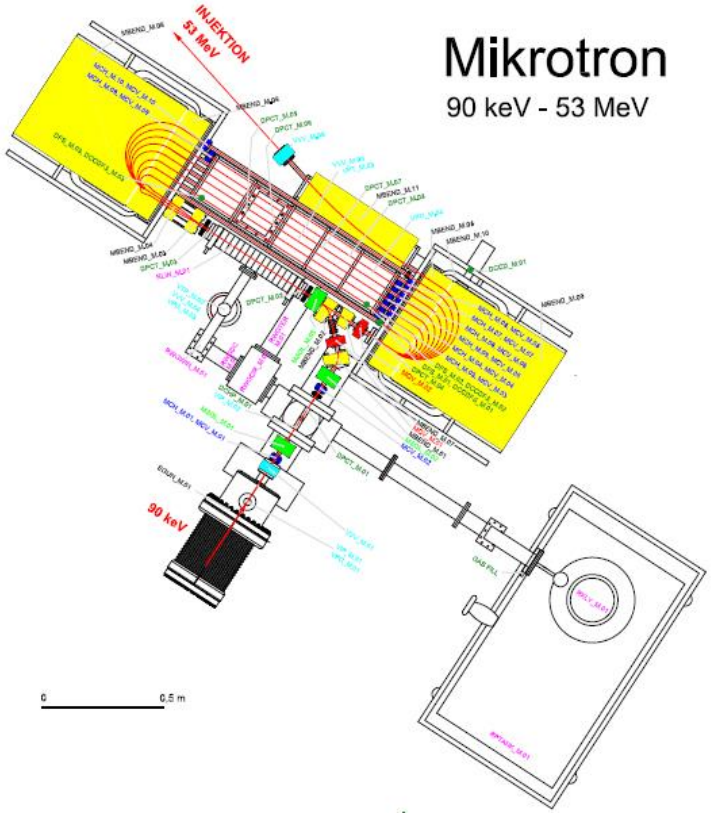
Booster

53 MeV - 500 MeV



Mikrotron

90 keV - 53 MeV

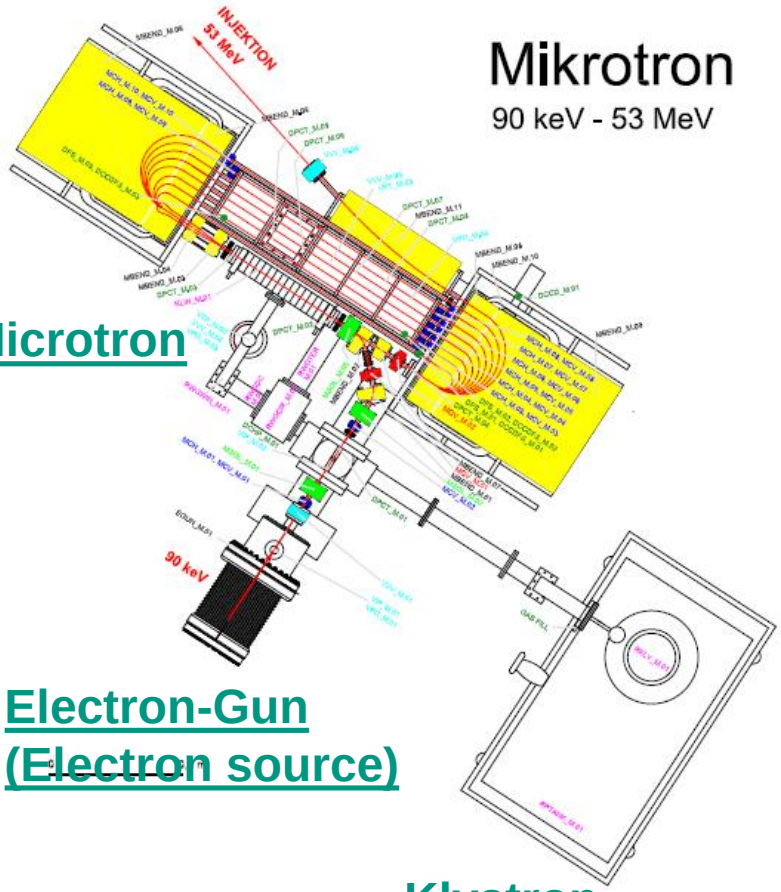


Beam Energy	< 500 MeV
Circumference	24 m
Harmonic Number	44
Number of RF Station	1
Operation Rep. Rate	1 Hz

Beam Energy	< 53 MeV
RF Frequency	2.999 GHz
Number of Turns	10 (up to 53 MeV)
Linac Structure	(1/2+7+1/2)Cells, Side Couple
Mode	Π/2 mode

Trouble Report in 2018 (1)

- RF-Breakdown in ***Microtron Linac***

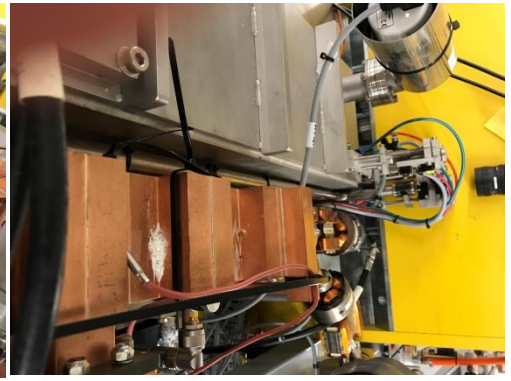


Microtron

Electron-Gun (Electron source)

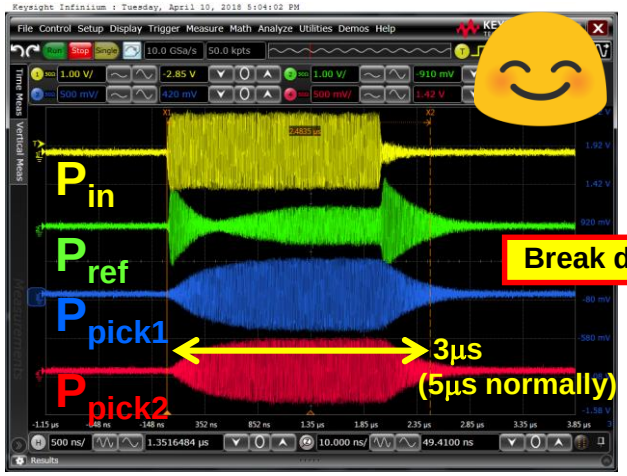
Klystron

- Klystron
  - 2.999GHz, Pulse-modulation
  - Peak power ~ 2MW (4MW maximum)
  - Pulse length: 5μs, Rep.rate: 1Hz
- Waveguide
  - From Kly. to Linac: Filled with SF6 gas
  - 1 Ceramic window (water-cooled)
- Microtron Linac
  - Water-cooled
  - 2 pick-up antennas



Trouble Report in 2018 (2)

- RF-Breakdown in Microtron Linac (about 20 years old)
  - 15.March.2018, RF-reflection power from the microtron linac became higher and intra-cavity power decreased drastically.



- The reflection power obviously increased.
- 2 pick-ups on the linac in different position had different pattern.

This could be from a local discharge inside the linac.

*Initially we suspected a discharge on the ceramic window in the waveguide, so we polished/cleaned it but it could not help us.

Trouble Report in 2018 (2)

- Time line from the failure until its recovery

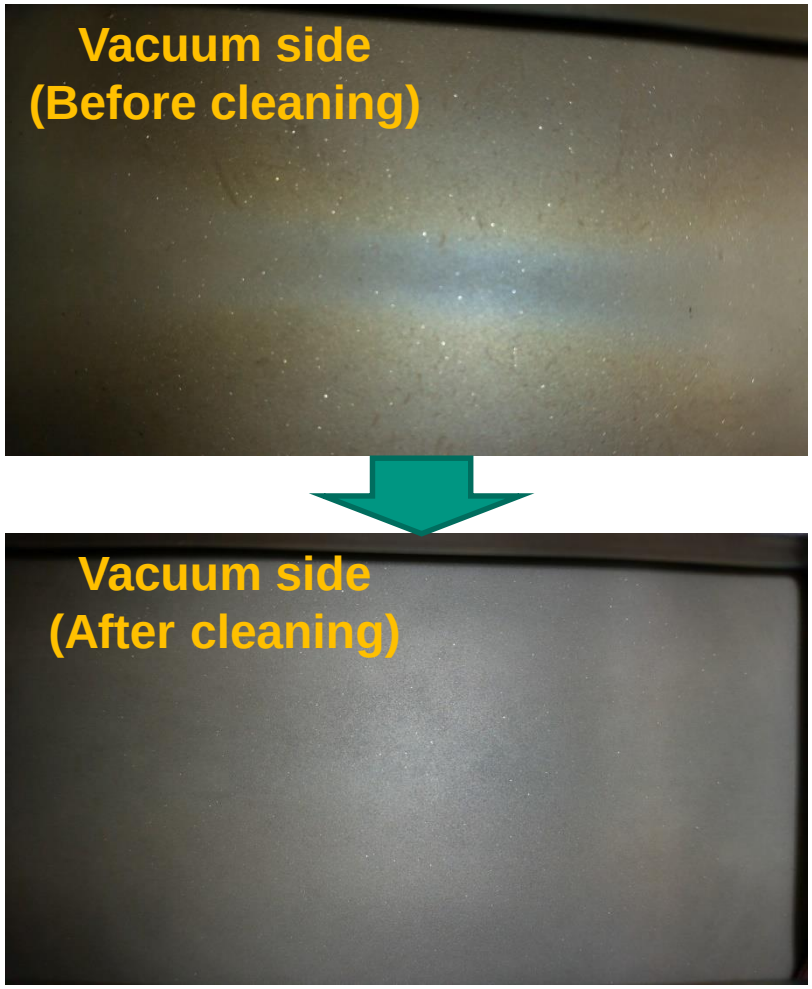
Date	Events
2018-03-15	RF Problem in microtron linac
2018-03-19	Open waveguide system and cleaned ceramic window
2018-03-21	RF power test with load ... The window was fine.
2018-03-23	Closed waveguide system and started bake-out
2018-03-26,27	RF commissioning: Not good condition.
2018-03-28	Dismount the linac for visual inspection (fiber scope)
2018-04-04	Cleaning with dry N2 gas
2018-04-06	Installed linac again and bake-out over weekend
2018-04-09	Started again RF commissioning
2018-04-19	Started commissioning with beam

We could receive a lot of helpful and kind comments and information from many accelerator facilities in the world.

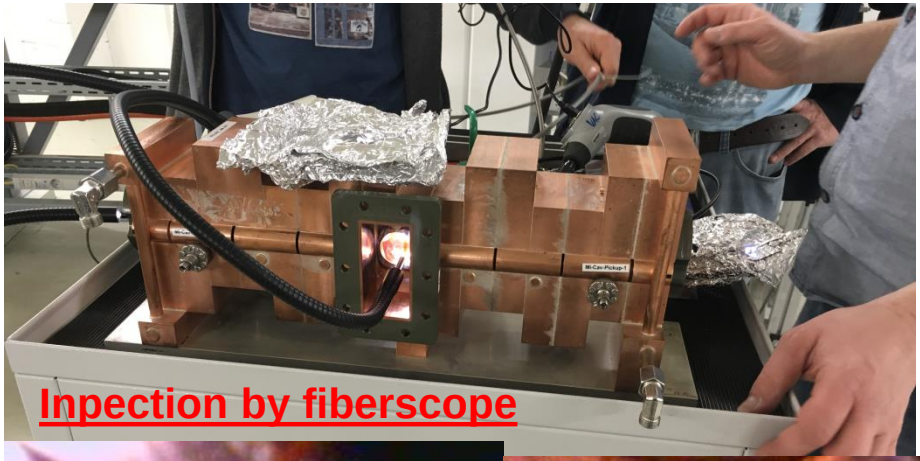
Thank you very much!

Trouble Report in 2018 (3)

Ceramic window in waveguide



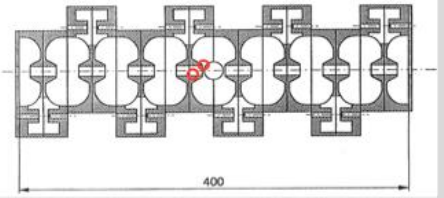
Linac dismount...



Inpection by fiberscope

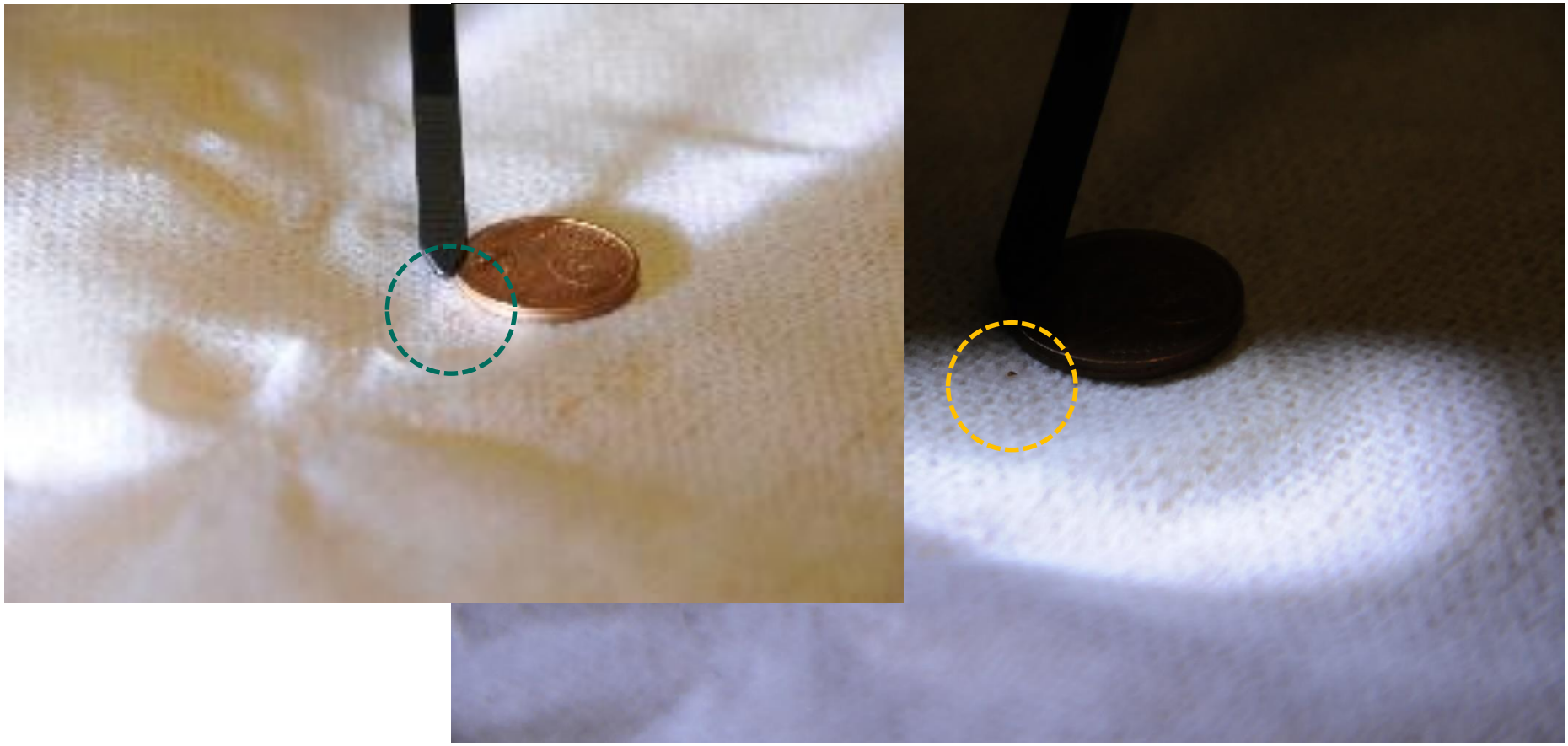
LINAC, principskiss

Some (discharge?) mark and a scratch were found around the nose cone.



Trouble Report in 2018 (4)

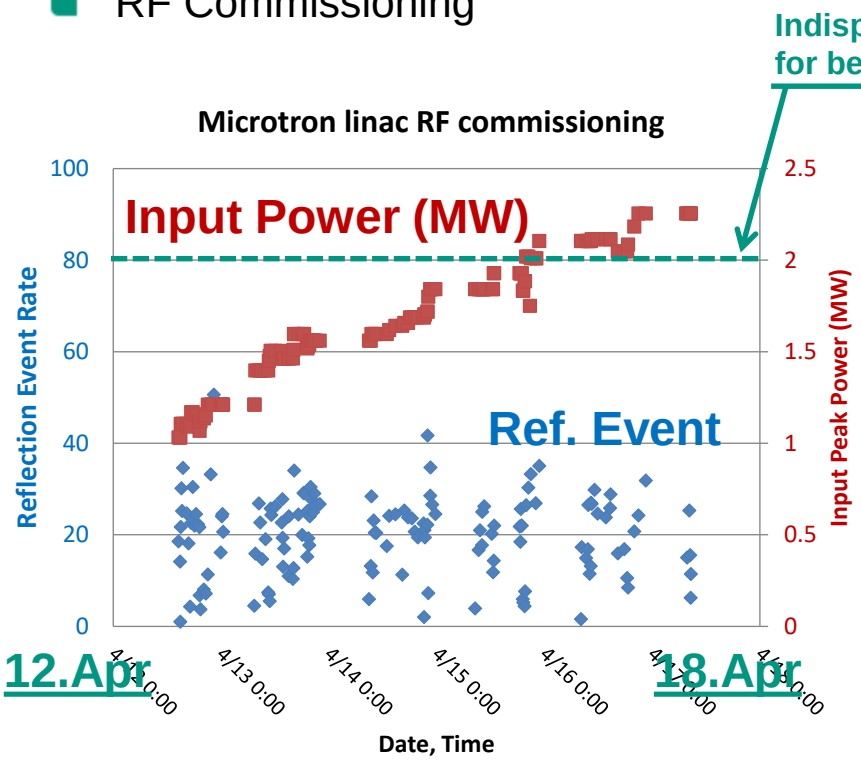
Blow cleaning with dry N2 gas

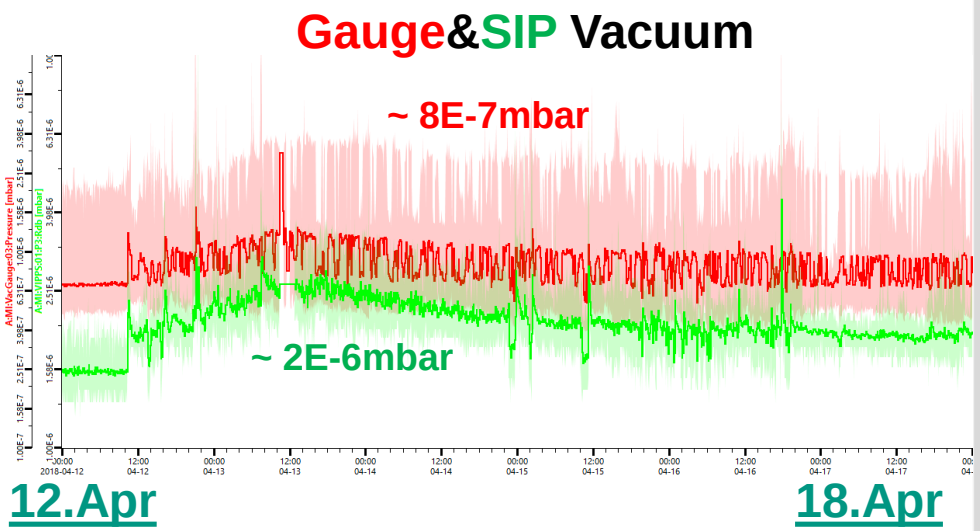


Copper-like grains came out of linac.
...where did it come from?

Trouble Report in 2018 (4)

- RF Commissioning





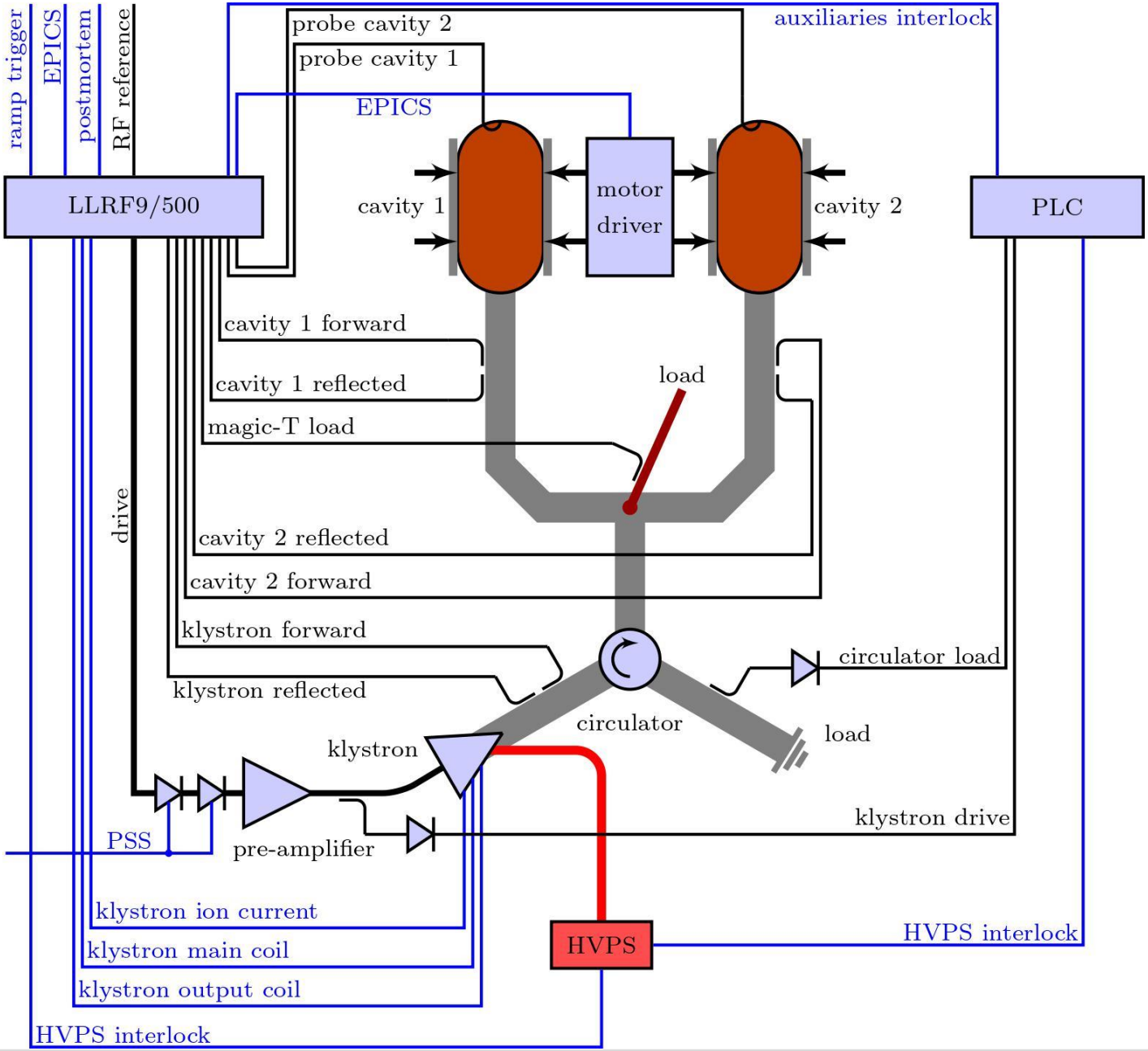
- The commissioning took about 1week from very low to sufficient power.
- Making a reflection-event counting system (by digital oscilloscope): commissionig by looking at the statistics.

The microtron has been recovered and is in operation now.

RF System in KARA Storage Ring (1)

Parameters	500MeV (Injection)	2.5GeV (User Operation)
RF / Revolution Freq.	499.7MHz / 2.72MHz	
Harmonic Number	184	
Total RF Voltage	300kV (Typ.)	1.4MV (Typ.)
Energy Loss per Turn	995.9eV	622.4keV
Synchronous Angle	0.05deg.	6.38deg.
Momentum Compaction	0.0105	0.00867
Synchrotron Frequency	35.0kHz	34.0kHz
Energy Spread (rms)	1.82×10^{-4}	9.08×10^{-4}
Bunch Length (rms)	8.67ps	36.9ps
Total Klystron Output	5.2kW (150mA)	140kW (140mA)
Ramping Time	-	3 minutes
Tuner Dead Band	0.1~0.5deg.	0.1~0.5deg.
Filling Pattern	Partical (30~33x3 bunches) or (30~33x4 bunches)	

RF Control in KARA



RF System in KARA Storage Ring (3)

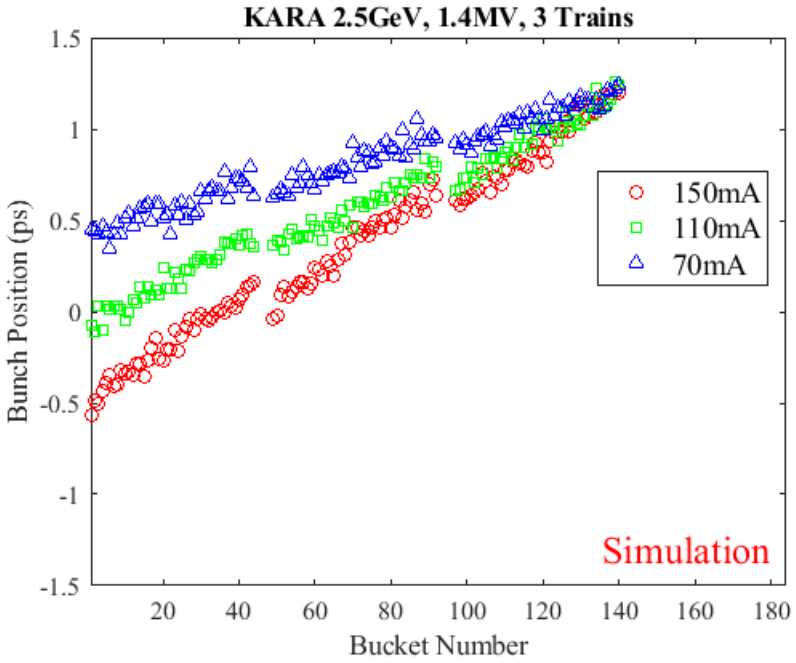
LLRF Controller: DIMTEL LLRF9/500

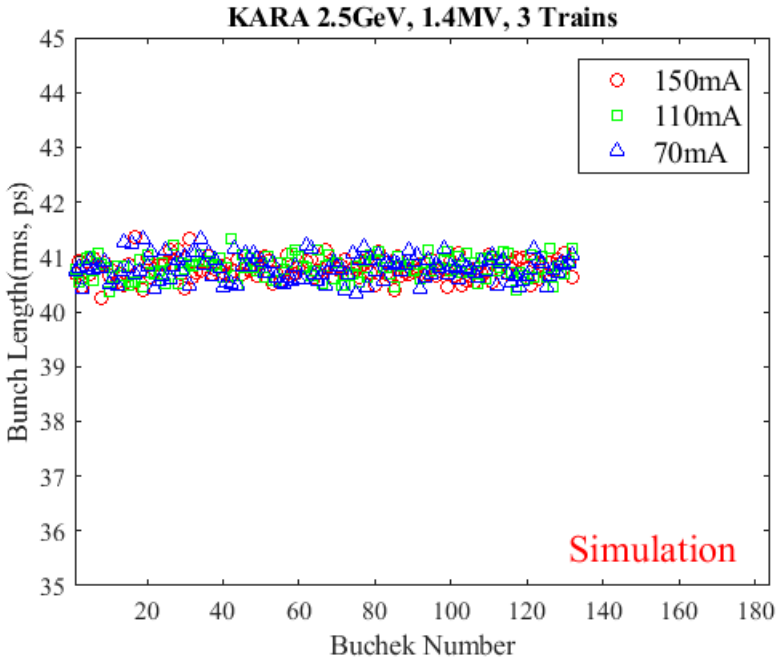
Signal	Symbol	Ratio to f_{rf}	Frequency (MHz)
Reference	f_{rf}	1	499.654
IF	f_{IF}	$\frac{1}{12}$	41.6378
Local oscillator	f_{LO}	$\frac{11}{12}$	458.0162
ADC clock	f_{ADC}	$\frac{11}{48}$	114.5040
DAC clock	f_{DAC}	$\frac{11}{24}$	229.0081

- 1-Module per 1-Station(2Cavs.)
  - Cavity pickups are vector-summed and proccesed in LLRF.
  - Phase adjustment between 2 stations are necessary.

RF System in KARA Storage Ring (4)

- Transient Beam Loading in Partial Filling (Simulation)
  - Bunch Arrival Timing: **1.5 ps** difference in 150 mA.
  - Natural Bunch Length ~**40 ps** (rms)



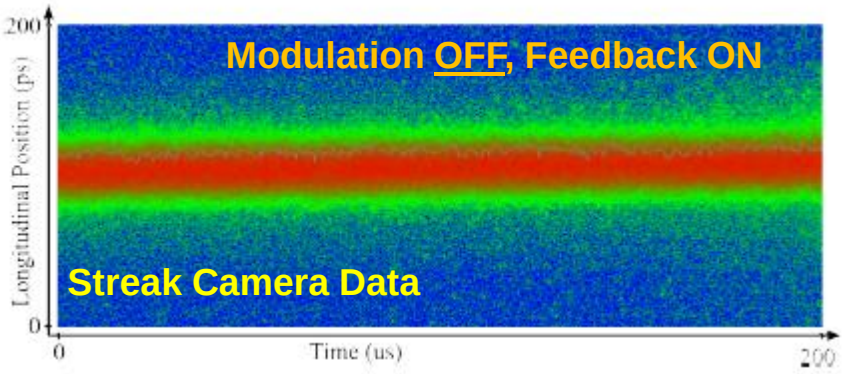


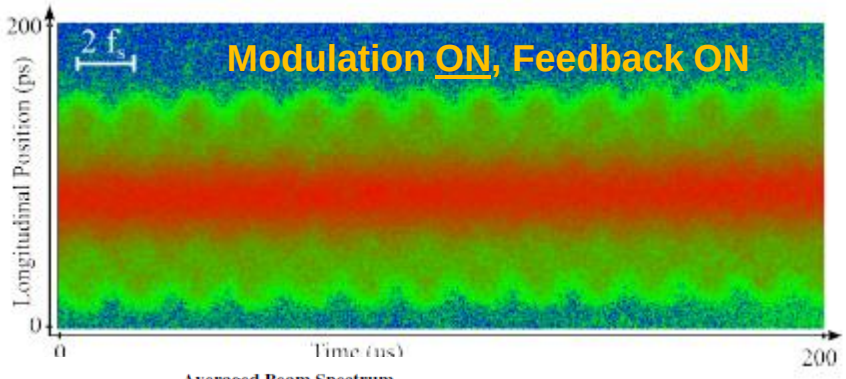
Difference in the arrival timing is negligible in KARA 2.5 GeV normal operation.

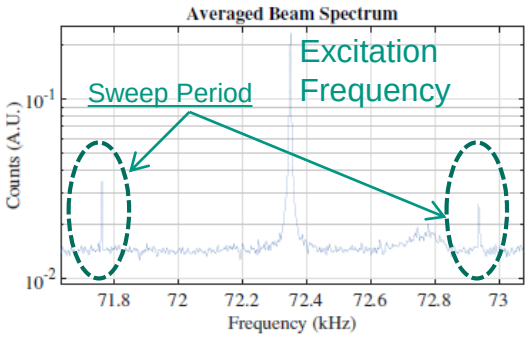
RF System in KARA Storage Ring: Operation(1)

- 2 Longitudinal Modulation Schemes
  - Modulation by Kicker Cavity
  - Phase Modulation by Main Cavities

- At the beam injection **(500MeV),** the kicker cavity is driven to excite quadrupole mode on the beam.
- The bunch lengthening occurs and the injection rate tends to be stabilized/improved.







Additional simulation would be necessary.

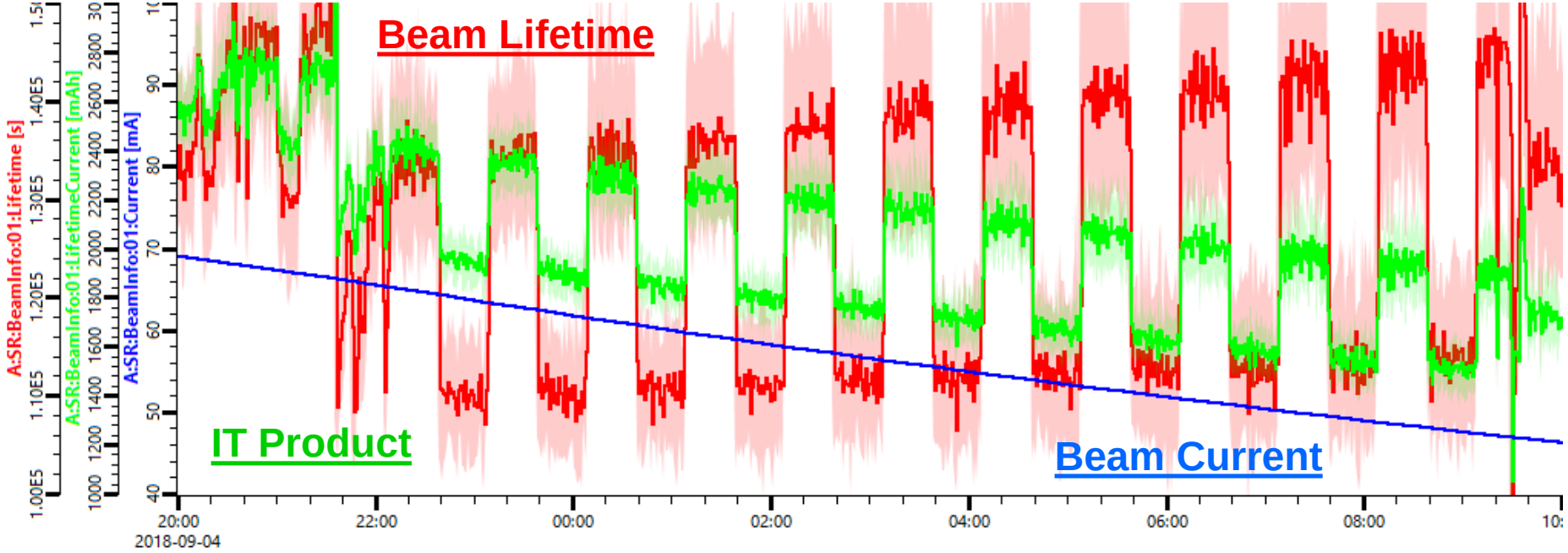
E. Blomley, M. Schedler and A-S. Müller, Proceedings of IPAC2016, p.2658-2660

RF System in KARA Storage Ring: Operation(2)

- 2 Longitudinal Modulation Schemes
  - Modulation by Kicker Cavity
  - Phase Modulation* by Main Cavities (R&D is now in progress)

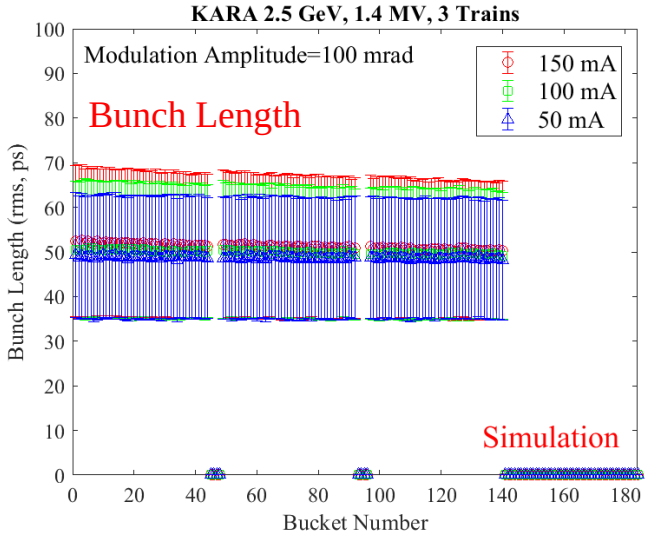
In 2.5GeV, the kick by the kicker cavity is too weak to excite the oscillation.
We have introduced a function of the phase modulation into the KARA LLRF on September 2018.

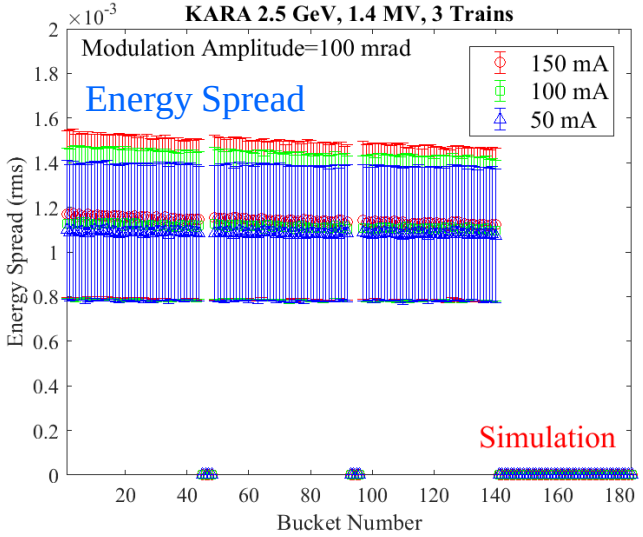
The First Trial of RF-PM in 2.5GeV

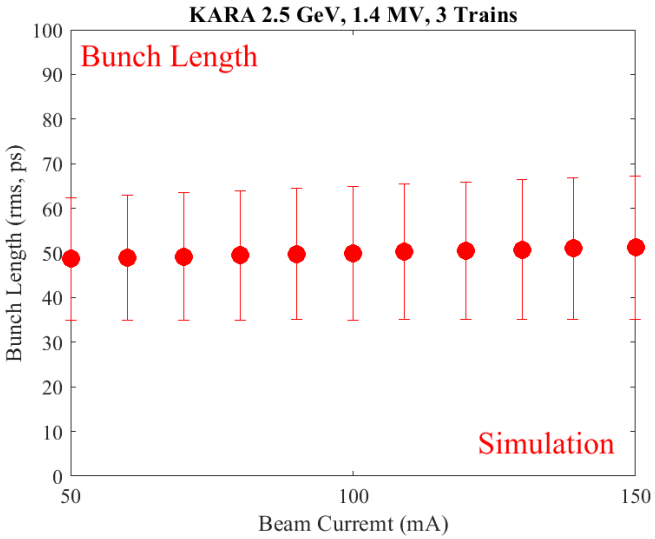


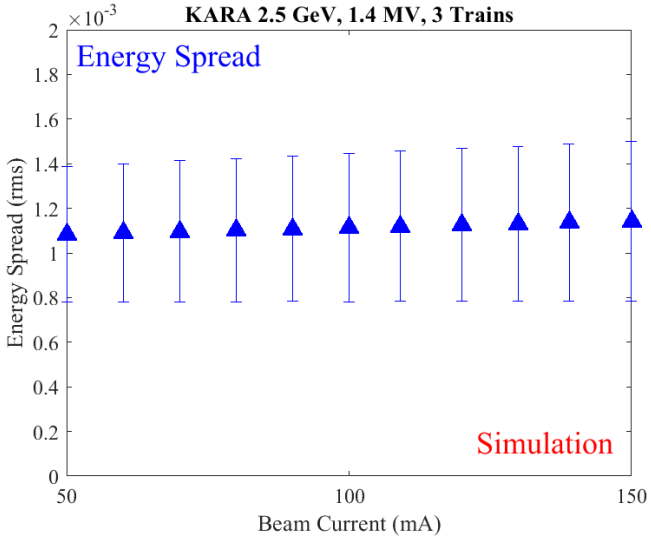
*S.Sakanaka et al., PRST-AB **3** 050701 (2000).

RF System in KARA Storage Ring: Operation(3)









The experiments to find an optimized condition are now under way...

We have to check:

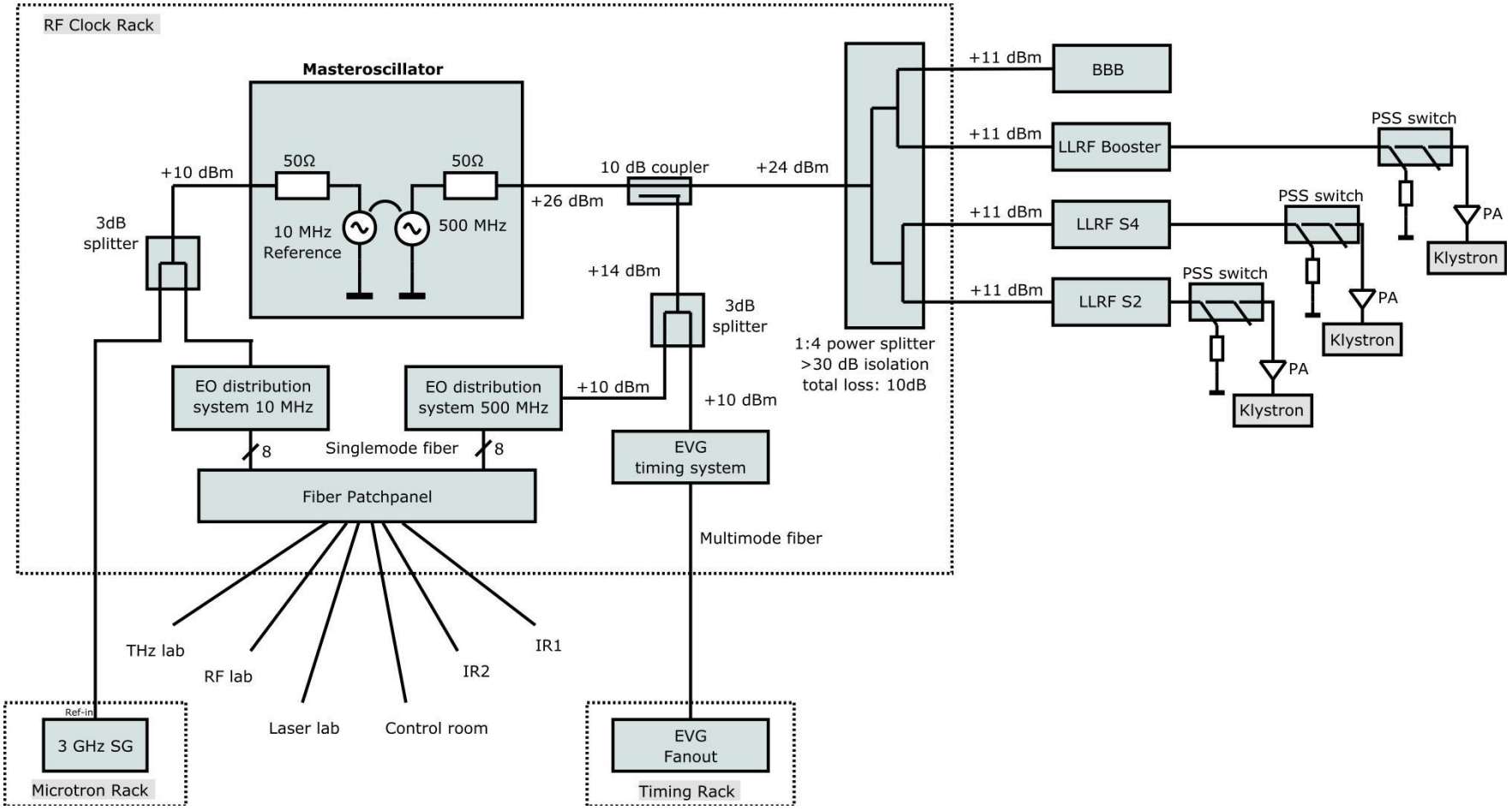
- Influence on the beamline (IDs).
- The other beam dynamics issues such as coupled bunch instabilities.

Outlook: Running Project NOW (1)

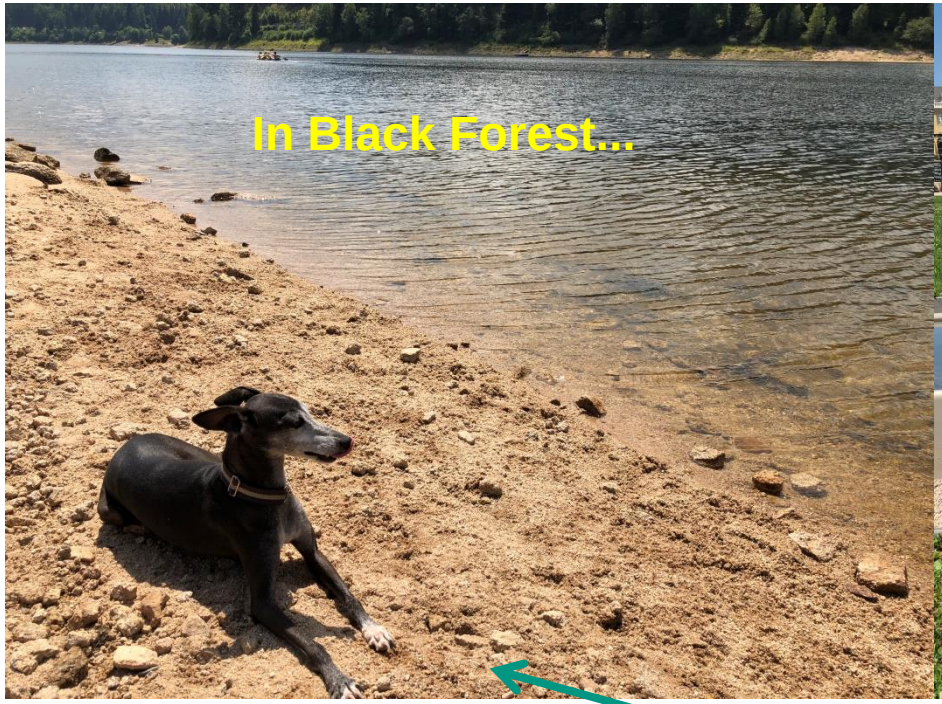
- Renewal of RF Cabinets, Re-cabling of LLRF System
  - Re-calibration of RF power from each component is needed: power meter, calorimetry / beam measurement
- New Master Oscillator
  - Rohde&Schwarz SMA100B: Low Phase Noise...-155 dBc/Hz (7.1 femto-sec. in 500 MHz)
- New Pre-amplifiers
  - Storage Ring: 500 MHz CW Pmax=50 W
  - Microtron / FLUTE: 2.999 GHz Pulse(Rep.Rate<10 Hz) Pmax=250 W(Peak)
  - Personal Safety System Interlock: The amplifier turns off when an alarm happens.
- Renewal of Klystron Protection System
  - Now: HVPS for KLY…PLC for water&air, self-made system for other issues
  - Plan: replacing the self-made system to LLRF, optical fiber for solenoid interlock

Outlook: Running Project NOW (2)

- Renewal of 500MHz Distribution System



Thank you very much for your attention!



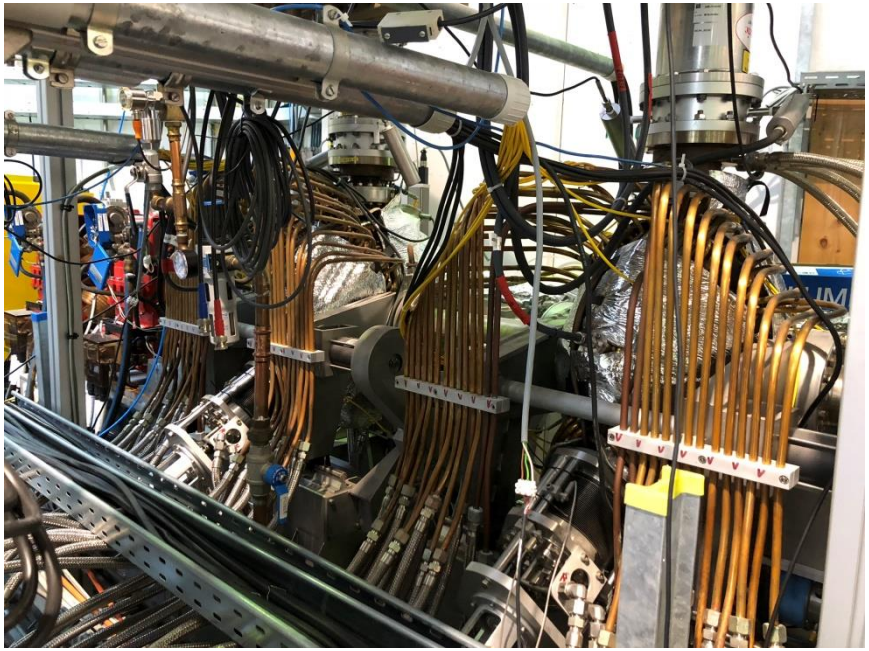
Rick(y)

Backups

RF System in KARA Storage Ring (1)

- Low Level RF System (19inch,1-rack)
  - Based on DIMTEL LLRF System
  - (Klystron, Cavity tuner) control
- Klystron, Circulator and Waveguides
  - 250kW Klystron (EEV), 1Klystron/Station
  - Circulator (AFT), Magic-T ... Split into 2 ports

RF System in KARA Storage Ring (2)

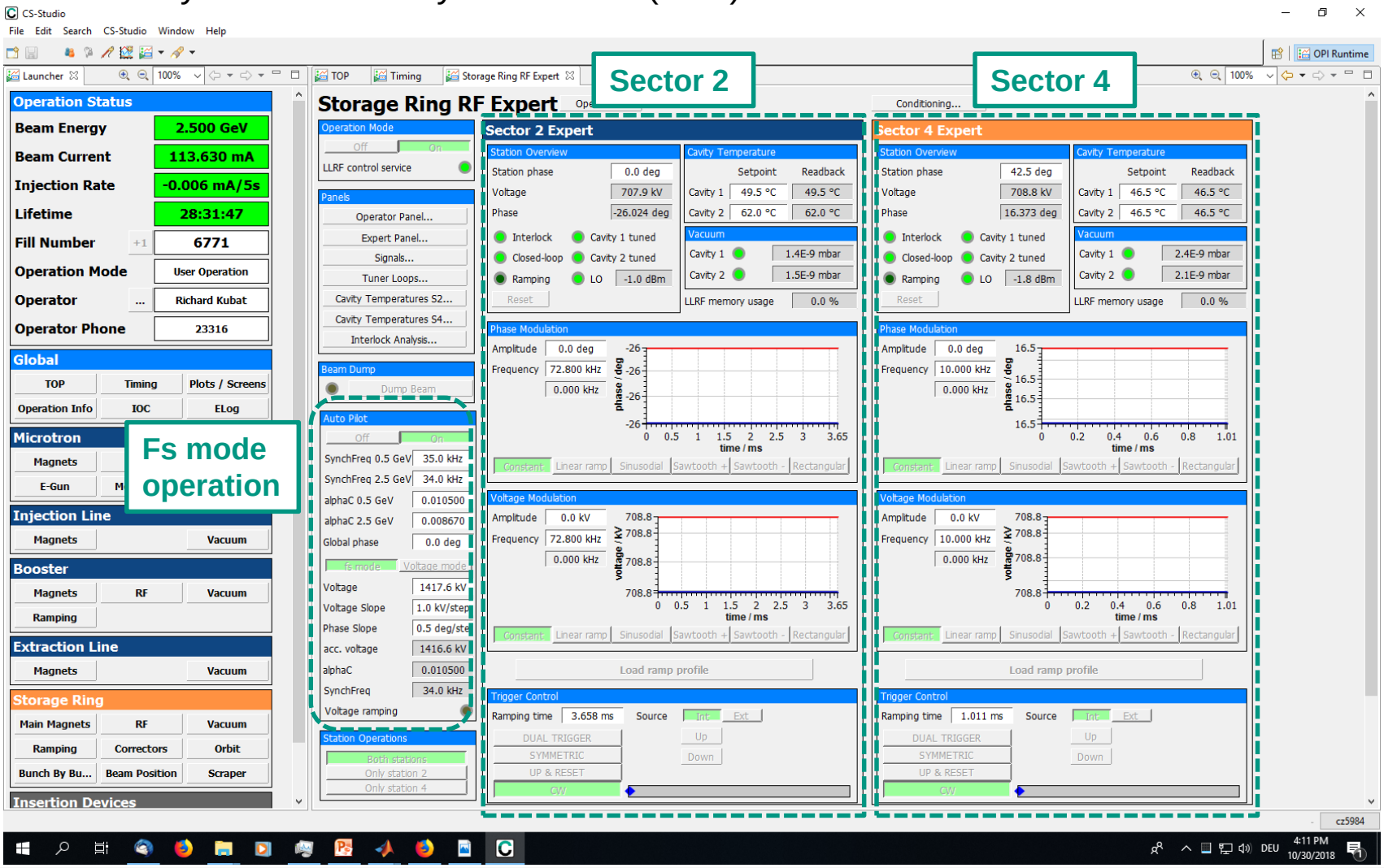


- RF Cavity (2Cavs/Station)
  - ELETTRA Type Cavity
  - Q0~40000, R_{sh}~3.3MΩ
  - Vc = 350kV/Cavity (@2.5GeV)
- Cavity Cooling System
  - 1-Chiller for each Cavity
  - Settled Temp. = 40~50degree
  - Controllable for each Cavity independently

The RF System in KARA is stably operated in daily beamtime.

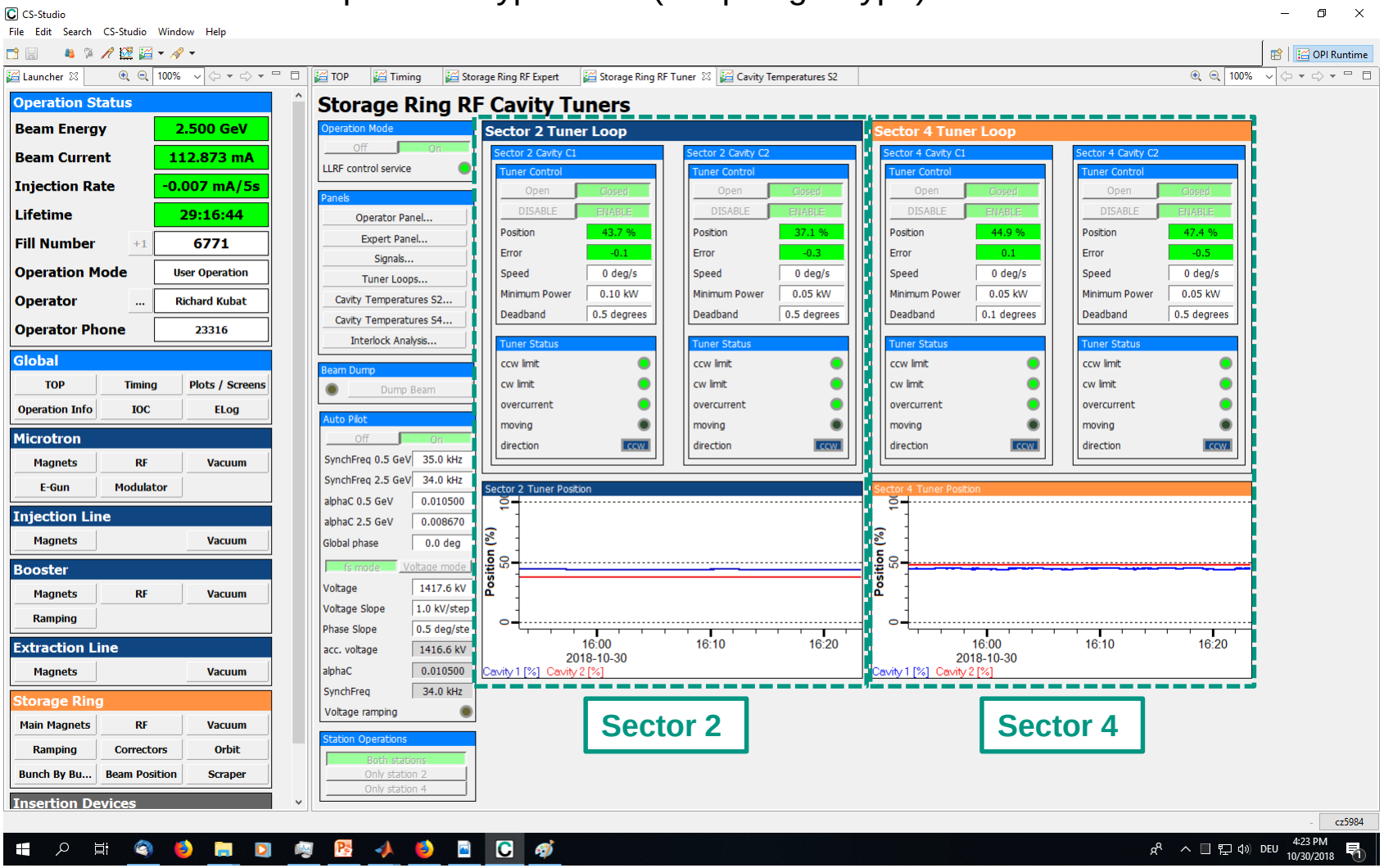
RF System in KARA Storage Ring (3)

- Control System: Control System Studio (CSS) & EPICS



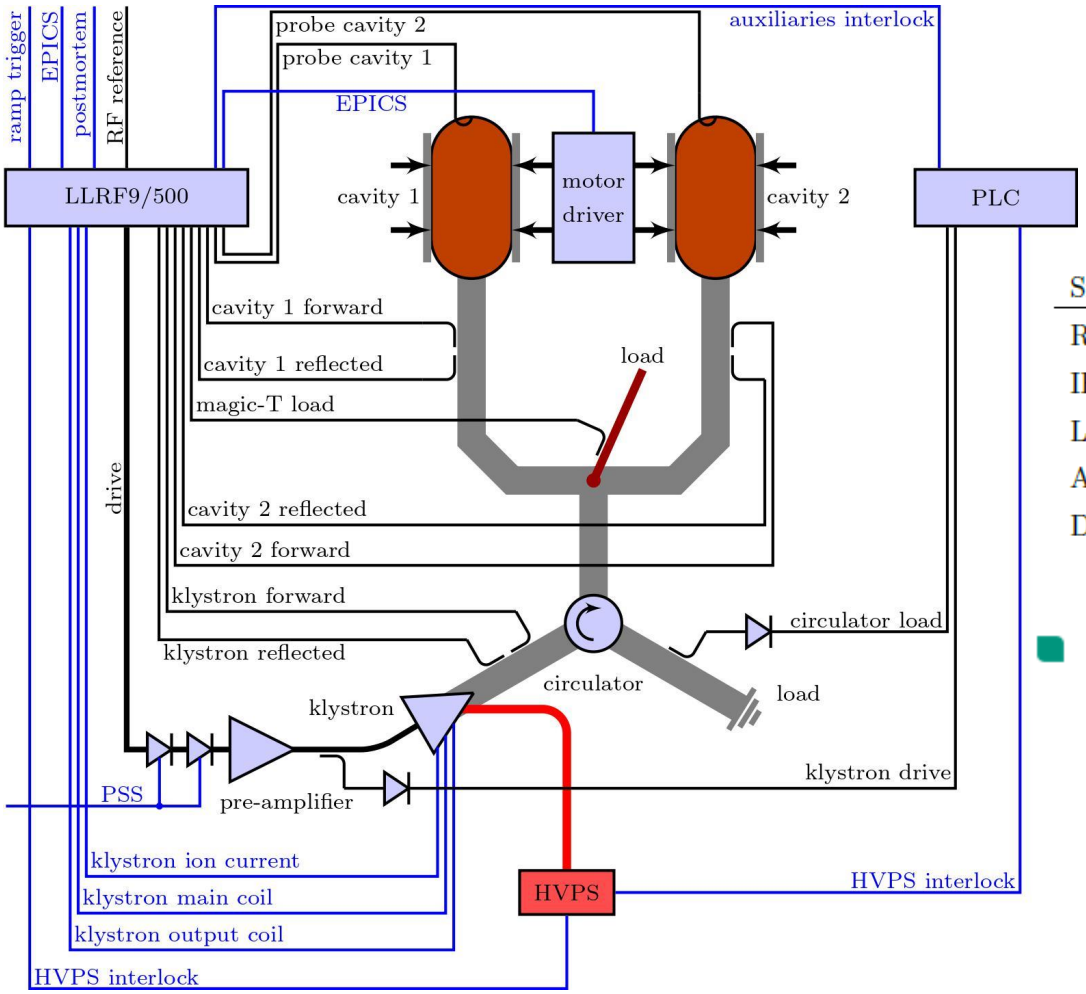
RF System in KARA Storage Ring (4)

- Tuner Control: Compression-type tuner (not plunger-type)



RF System in KARA Storage Ring (2)

- RF Control System in KARA



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