

PAUL SCHERRER INSTITUT

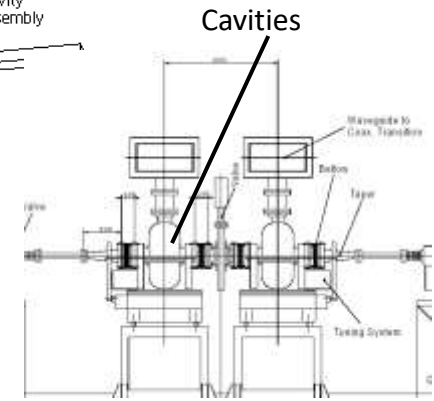
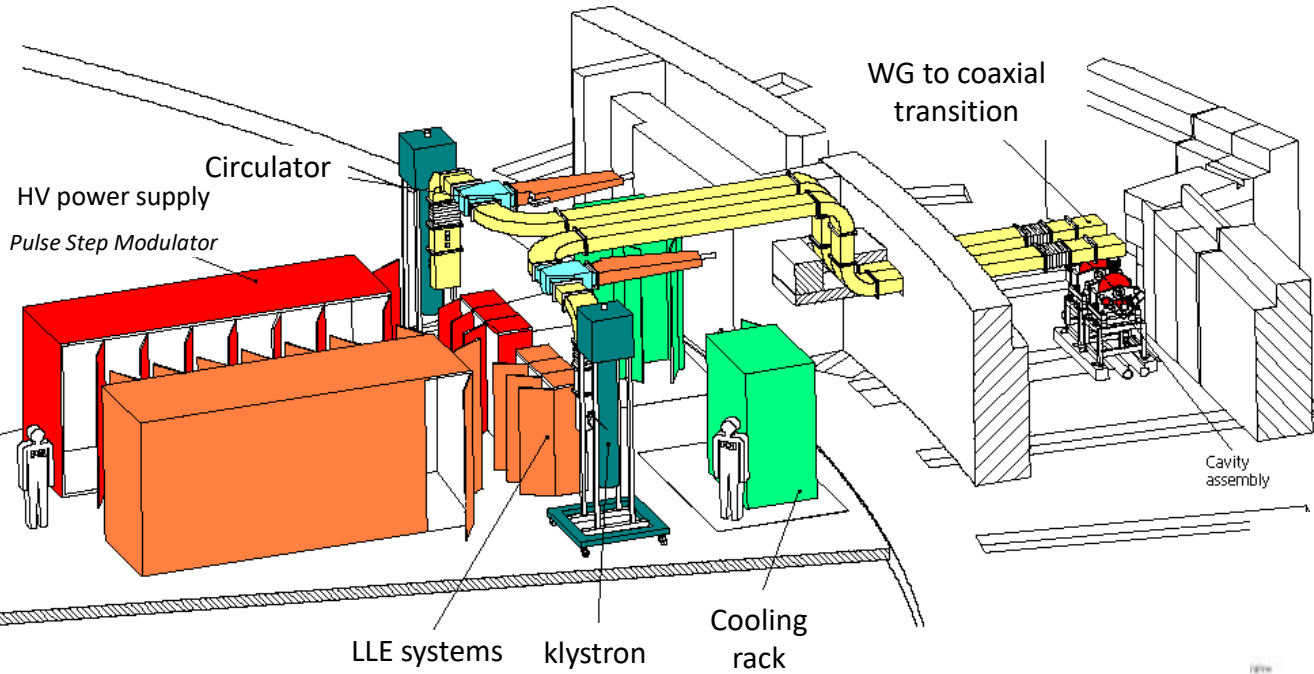


Lukas Stingelin :: RF-Systems 1 :: Paul Scherrer Institute

Operation and Upgrade of the SLS RF Systems

Ampegon User Workshop, April 2024

Facility overview: 5 independent 180 KW RF plants



Facility overview: Pulse Step Modulator



Series TSM6 power module

700V-DC, max 25 A.

Switches: Insulate-Gate Bipolar Transistor (IGBT)

Replaced all electrolytic capacitors!

5 identical HV pws

Globally 340 modules

4 module failure in first 4 Years!

Each module supplied from a separated secondary winding of a multi secondary power transformer

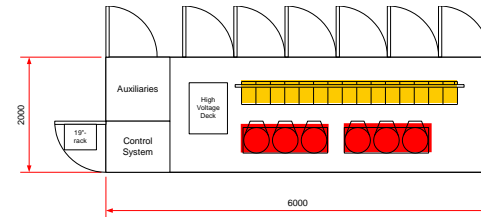


Globally 68 modules - series connected

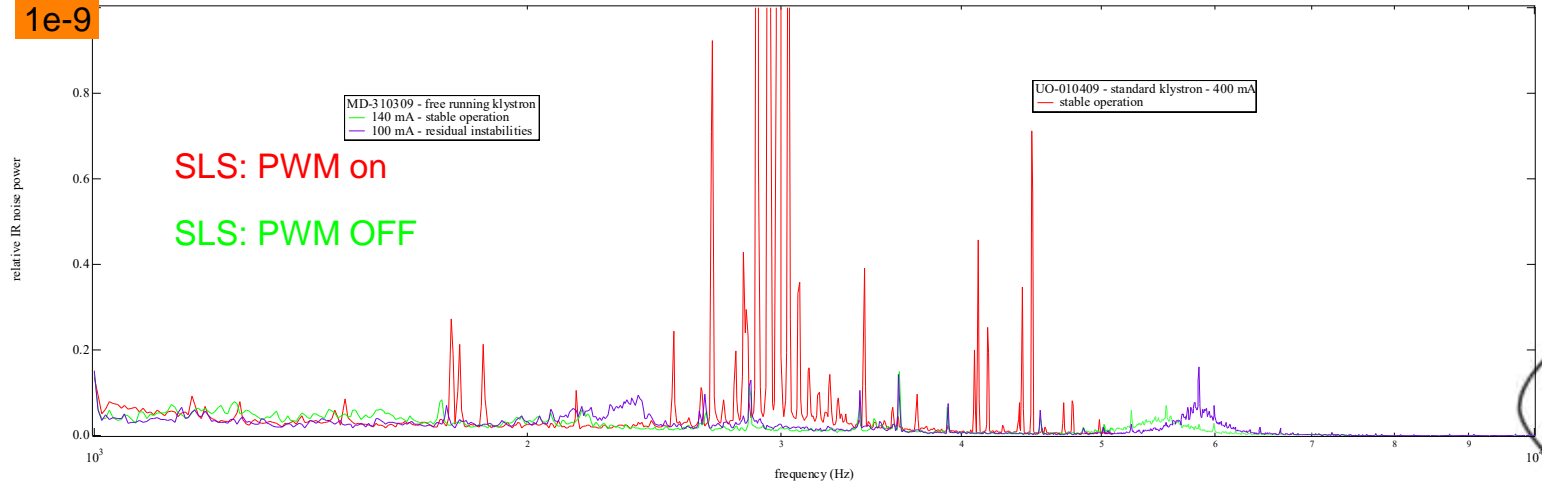
46 kV / 7.5 A

Efficiency: 96%

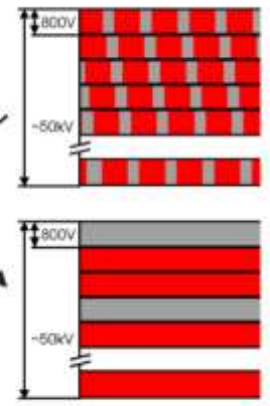
Short circuit energy: <15J (no crowbar)



1e-9

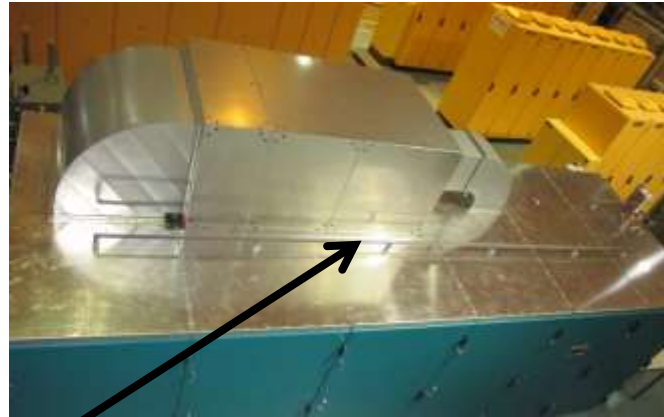


✓ Since January 2010, HVPS for Klystrons run without PWM and rotation.



Assessing noise sources at synchrotron infrared ports, Ph. Lerch et al.
 Journal of Synchrotron Radiation, Volume 19 | Part 1 | January 2012 | Pages 1-9
<https://doi.org/10.1107/S0909049511041884>

Fire- & Discharge protection for Klystron Supply Unit



Smoke-Detector → Switches the klystron supply unit off and alarms the fire brigade



UV-Detector → Switches the klystron supply unit off and alarms the control room

Refurbishing and Efficiency of EEV 500MHz Klystron.



EEV Type K3418P
Klystron

cavity 3
(2nd
harmonic)

cavity 2

cavity 1

e-gun

✓ First EEV Klystron sent to CPI for Refurbishing in 2009

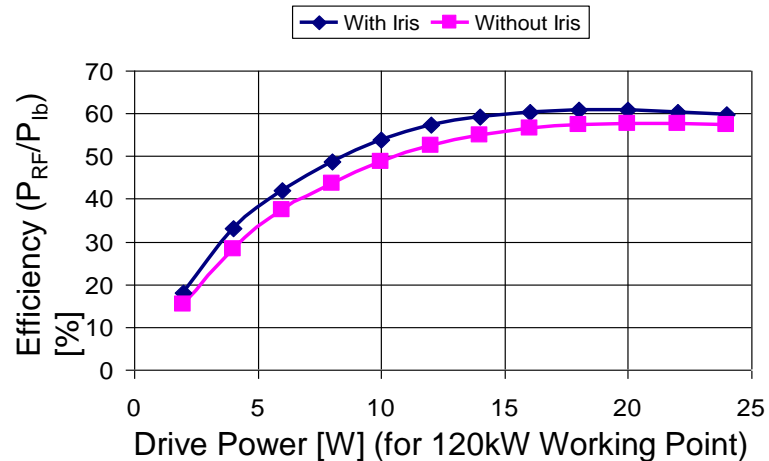
✓ FAT in Palo Alto CA successful

☒ However, problems at PSI to reach maximum output power

→ 2nd harmonic cavity had to be retuned

☒ Efficiency not optimal

→ Attempt to adjust matching with Iris



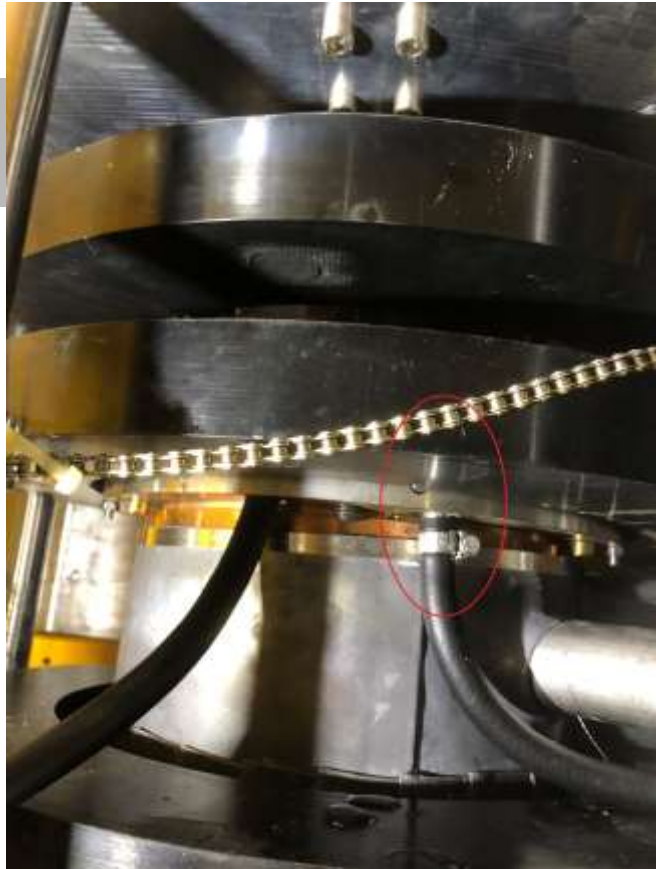
Coincident arc detection on the klystron and circulator

Motive for improvement:

- Several arcs per month and RF plant
- RF plant stop
- Beam loss



Water Leaks at 500MHz Thales Klystrons



Leak was repaired by flame-brazing, unfortunately, several other leaks were found and had to be brazed

Problems with EEV 500MHz Klystron I



EEV Type K3418P Klystron

- Second EEV Klystron sent to CPI for refurbishment. Big delay!
Improvement of matching, resp. efficiency is expected

- ☒ Water leak at first refurbished klystron after 6 months of operation



- ☒ Water leak at booster klystron

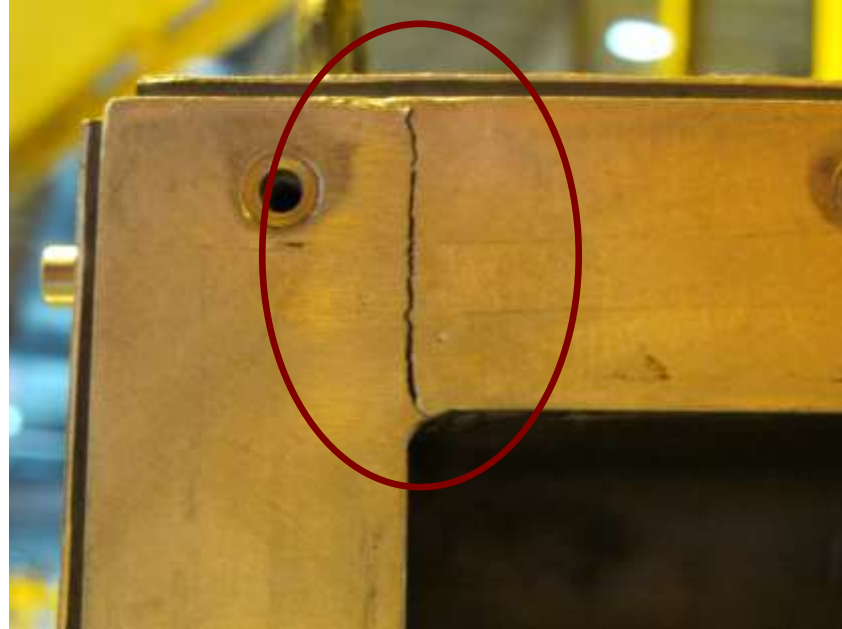


Problems with EEV 500MHz Klystron II



EEV Type K3418P Klystron

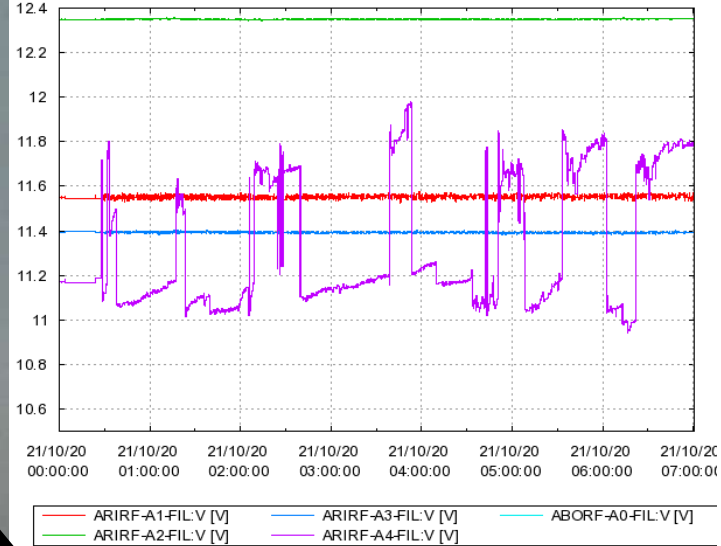
☒ Fissures at frame of HV-box (→ temporary fix with bands and successive replacement by rewelded + reinforced frame)



Problems with «Pantak» Connector of 500MHz Klystrons



→ Filament overvoltage interlocks:

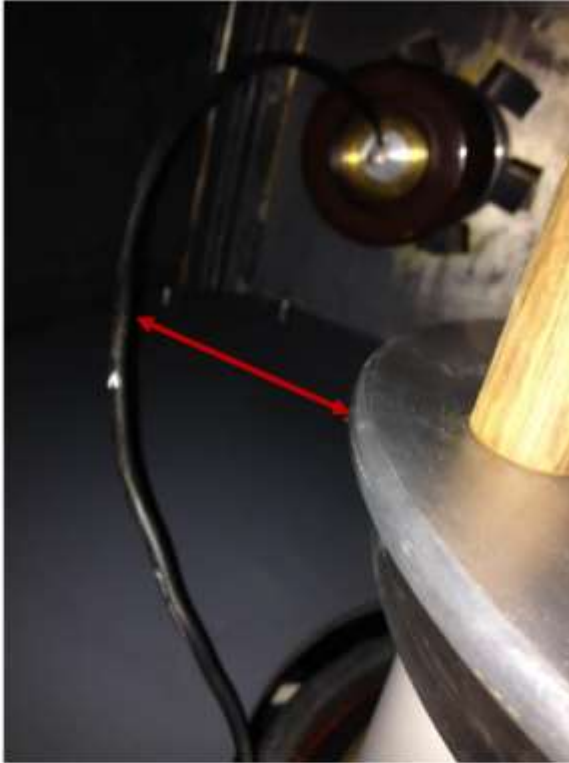


Bad contact at the tip → re-soldered,

No contact at the «shield» → Added copper disks

→ later improved pins for higher current operation!

Issues with Mod. Anode Interlocks and Vacuum Pumps



HV-deck of EEV Klystron
(cable was too close to the ring)

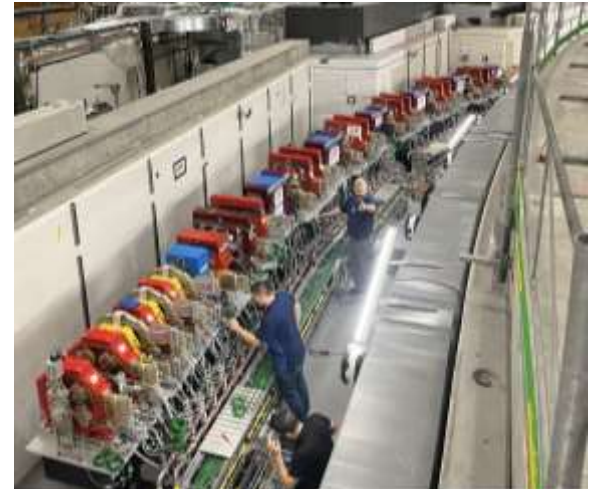


Connector of Klystron vacuum pump

- ✓ Arcing of modulation anode cable caused 5 hours downtime of booster RF-plant
- ✓ Vacuum problems, marks on IP-ceramic after high-potting
- Efficiency of refurbished klystron below specification
- ✓ Vacuum problems solved by high-potting on refurbished klystron

SLS 2.0 Upgrade Project Schedule

Key Milestones: Version March 2024 ~ TDR 2021



SLS 2.0 Synchrotron Parameters

	SLS 2.0 (TDR)	SLS
Circumference [m]	288	288
Energy [GeV]	2.7	2.411
Natural emittance [pm.rad]	158	5700
Lattice and ID energy loss/turn [keV]	687.6 → 943	549→600
Energy loss/turn in wake fields [keV] w. (w.o) 3HC	7 (22)	
Energy spread	$1.16 \cdot 10^{-3}$	$9 \cdot 10^{-4}$
Momentum compaction α_c	$1.05 \cdot 10^{-4}$	$7 \cdot 10^{-4}$
Energy acceptance (without harmonic cavity)	6.2% → 5.1%	3%
Main RF frequency [MHz]	499.6537	499.6
Total main RF voltage nominal [kV]	1780	2080
Harmonic number	480	480
Gap in the filling pattern, empty buckets	20... 30	50...90
Damping times x/y/E [ms]	4.14/7.54/6.41	8.4/8.4/4.5
Longitudinal stability threshold per cavity [GHz k Ω]	6.2	
Horizontal stability threshold per cavity [M Ω /m]	3.3	40
Vertical stability threshold per cavity [M Ω /m]	4.4	
Beta functions at main cavity location β_x [m] / β_y [m]	9.6/7.0	1.5/1.1
Beta functions at harmonic cavity β_x [m] / β_y [m]	6.8/4.1	3.5/3.5
Synchrotron frequency without harmonic cavity [kHz]	2.172	6.93
Energy fluctuations relative to energy spread	<10%	



➔ **New HOM damped cavities
from Research Instruments
(4+1 spare)**

SLS 2.0 RF parameters

Main RF-System	SLS 2.0		SLS
Total voltage [kV]	1440	1780	2080
Energy acceptance (without harmonic cavity)	5% → 3.7%	6.3% → 5.2%	3%
Number of cavities	4		4
Voltage per cavity [kV]	360	445	520
Wall loss per cavity [kW]	20	30	40
Required RF-power with beam and minimum ID Power [kW]	88	98.1	95
Required RF-power with beam and maximum ID Power [kW]	114	124	100
Optimal coupling	4.62...6.0	3.4...4.3	2.5
Detuning for matching [kHz]	-49.1...-57.1	-32.4...-44.6	-33
HOM control	By strong HOM damping		Temp. detuning
Max. voltage for ≤150kW reflected pulse power [kV] (restriction from amplifier specification)	460	540	



Amplifier Spec: 150kW
4 SSAs ordered from Cryoelectra

Power Economy SLS2.0 vs. SLS incl. PV roof

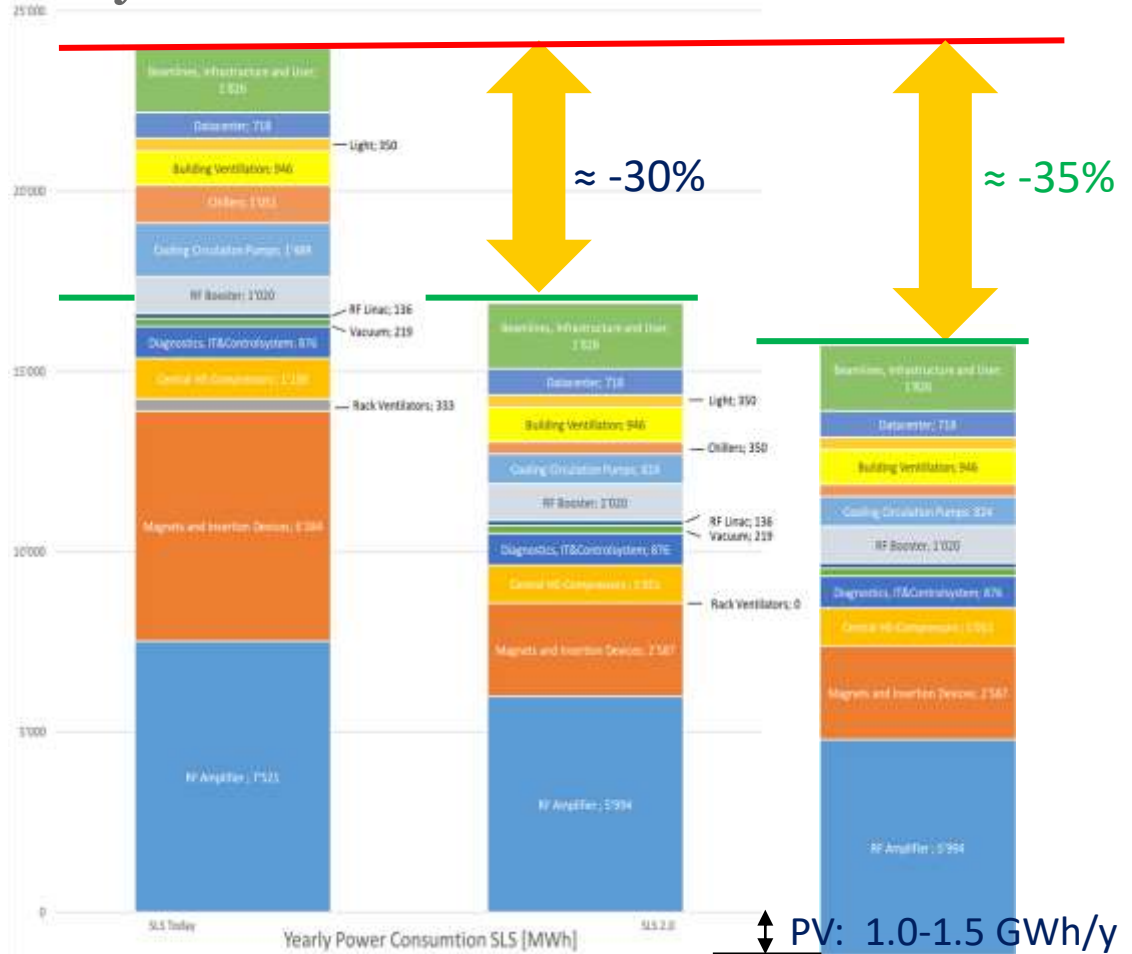
More radiated X-ray power for users
Less electricity consumption

SLS → SLS2.0

E_e	2.4 GeV → 2.7 GeV
P_{SR}	310 kW → 365 kW
W_{elec}/y	24 GWh → 17 GWh
$W_{elec} - W_{PV}/y$	17 GWh → 15.5 GWh

Key savings:

- Electromagnets → permanent magnets
- Klystrons → solid state amplifiers**
- Standard pumps → regulated pumps for cooling
- Tar paper roof → PV cladded roof



SLS 2 & SLS Renewal from RF Point of View

(BPMs, MBFB, Injection not included in slide)

S3HC new position (new position)

- Refurbishing Tuning Syst.
- Upgrade LLRF
- *Refurbishing Cryogenics (9372)*

Consolidation Booster RF station

- New LLRF
- Replace Acc. Cavity

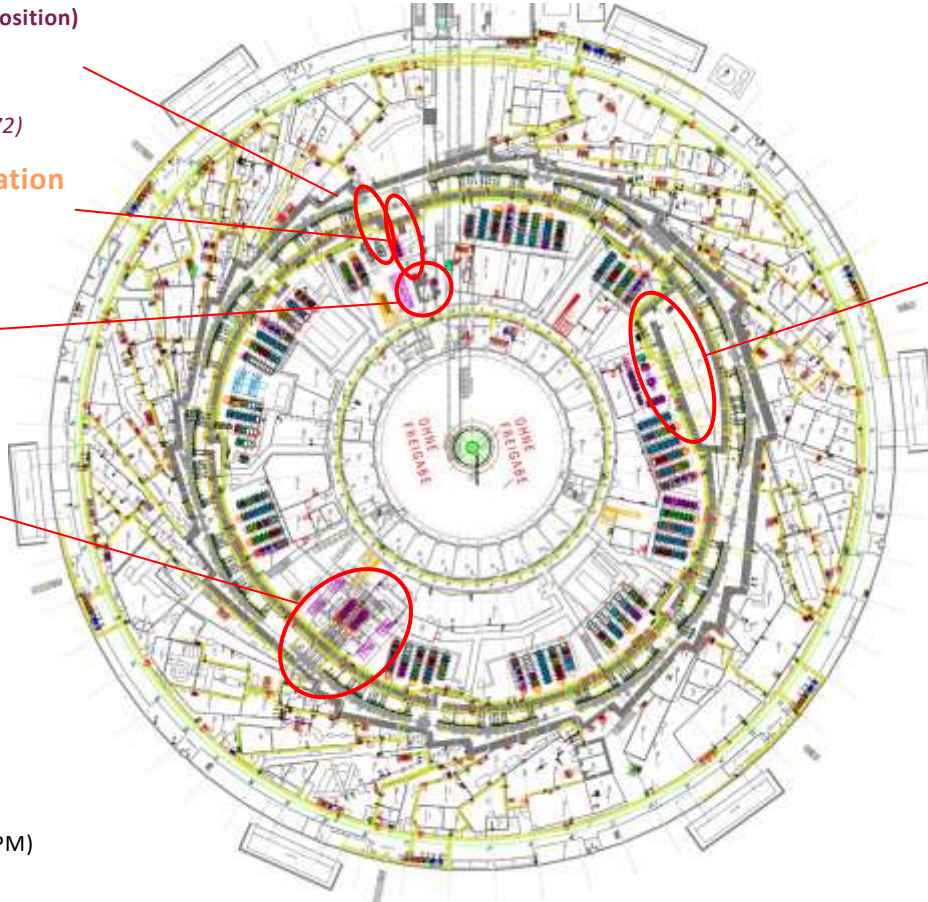
Renewal 500 MHz Tests stand

New SR-RF-stations (new position)

- New amplifiers
- New acc. Cavities
- New LLRF

General tasks

- Distribution 500 MHz reference
- Simulation wake field & SR instability thresholds (never ending task)
- RF design of components (Example BPM)

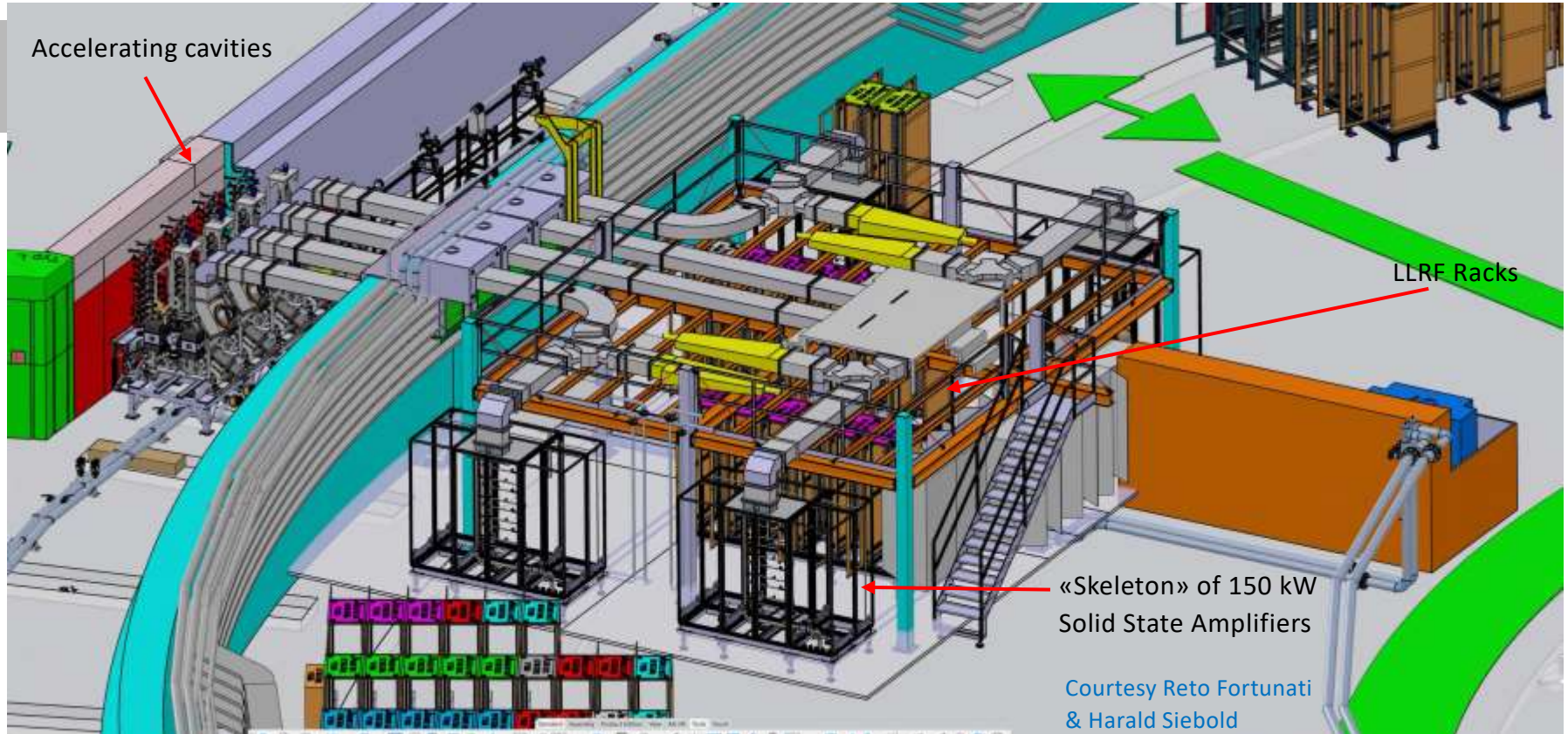


Linac renewal

- Modulators controls + Tank (2024)
- PSYS interfaces (2024)
- Consolidation Waveguide and acc. Structures (2026)

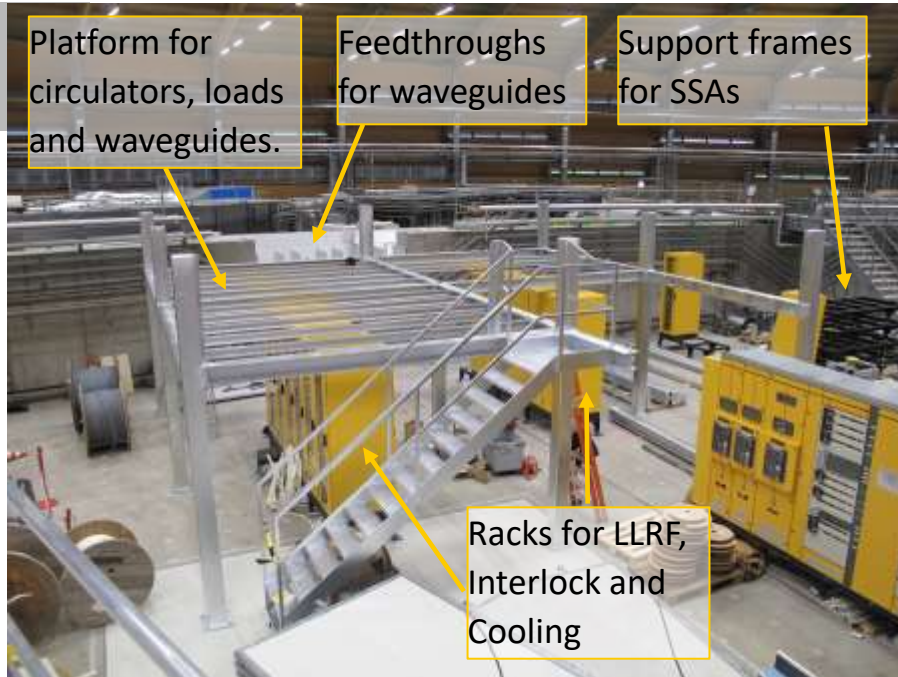
SLS 2: Storage Ring Accelerating Stations

RF Power station layout implementation in straight X05



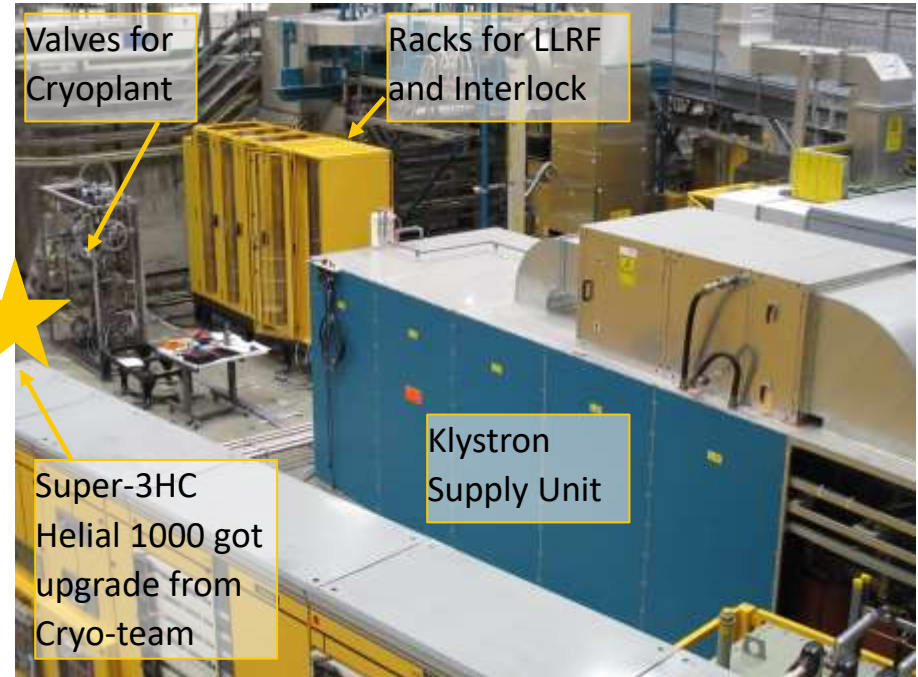
Status of RF-Installation Area

Storage Ring 500MHz-Systems:

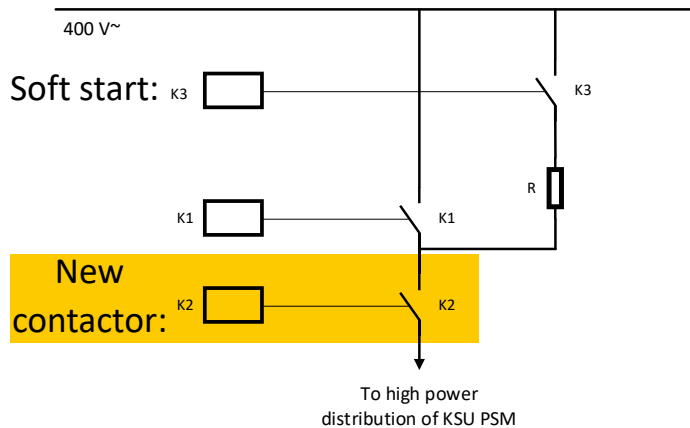


Installation of platform, cooling, waveguide feedthroughs and shielding in progress.

Booster RF and Super-3HC Cryogenic-System:



Cabling ongoing, beginning of teststand operation from Mai 2024. **Amplifiers need safety upgrade**



- For new safety regulations, performance level PLe or PLd will be required when the amplifier is disabled by the personnel safety system
- Redundancy of the main contactors is required!
- Also, new test-mode and emergency-stop functionalities are required.

SLS Klystrons and Klystron Supplies Currently on Stock:



Questions?

