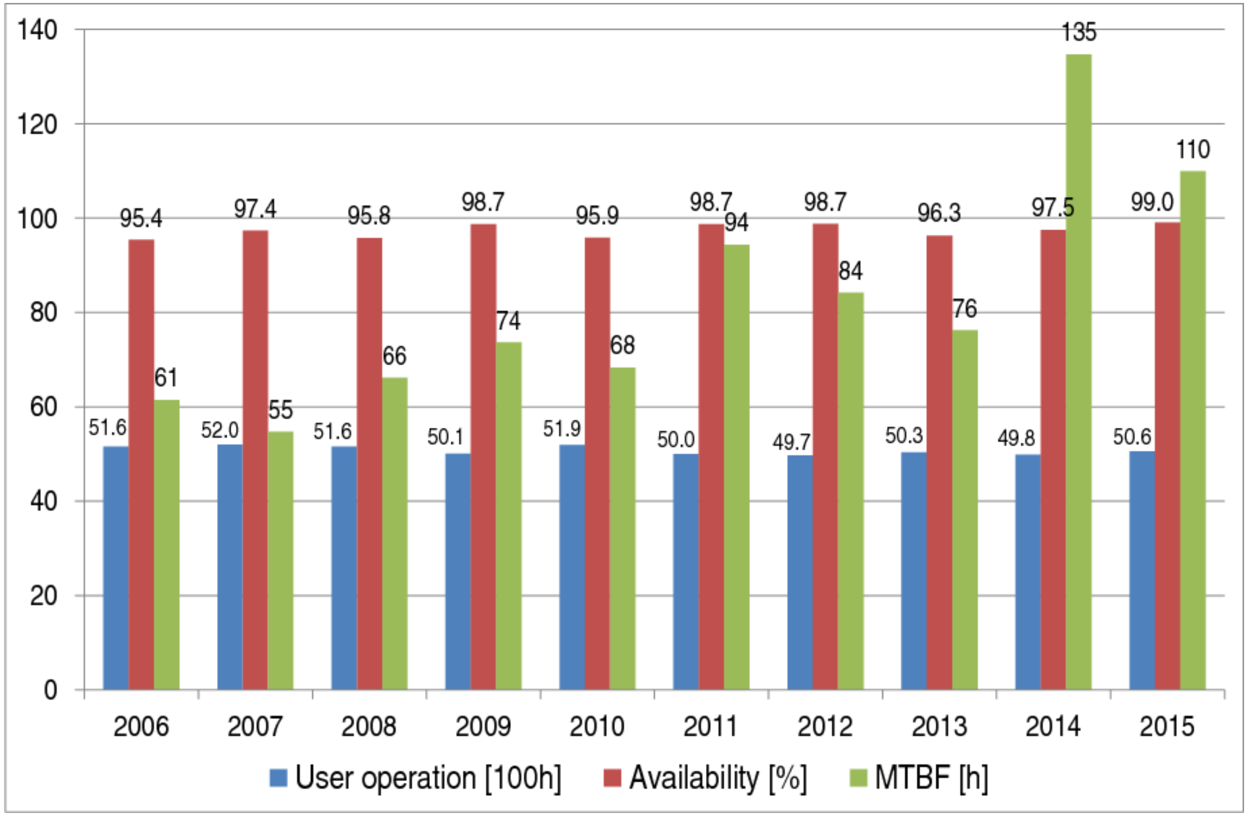
PAUL SCHERRER INSTITUT PSI

20th ESLS RF workshop 2016

RF operation at the SLS and status of the SLS2 proposal

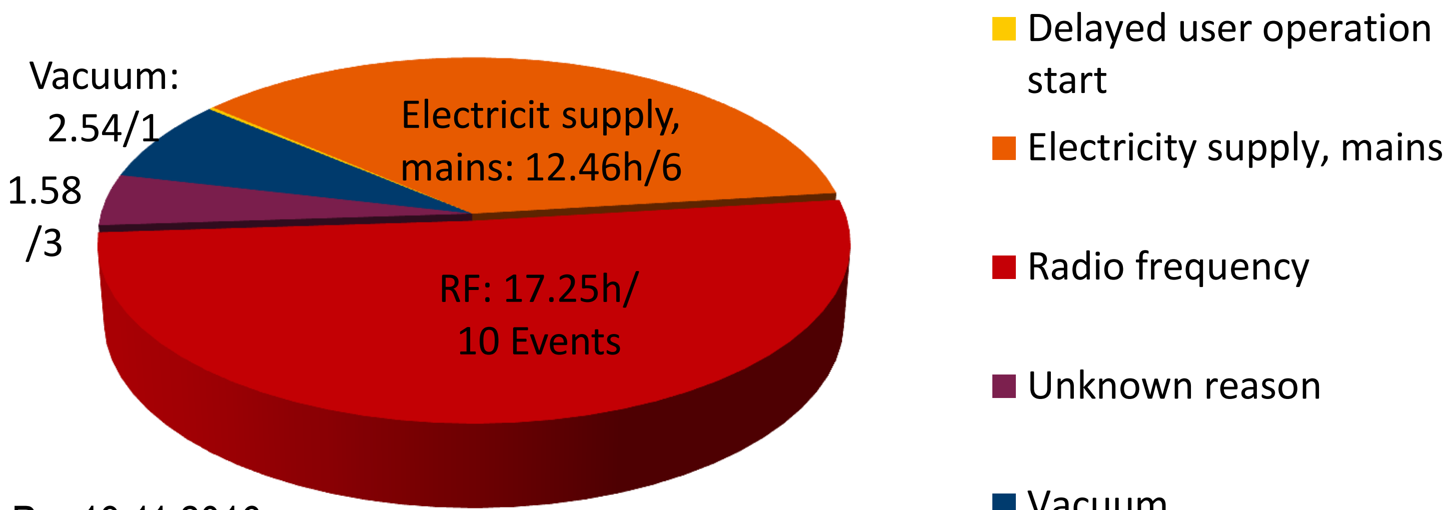
Lukas Stingelin and Haisheng Xu for the PSI RF group

Operation Statistics 2015



- **Failures at LINAC: power supplies (refurbished), klystron body flow meter (replaced)**
- **Failures at storage-ring: klystron vacuum-pumps (sent to repair), false interlocks.**
- **Problems with S3HC: power failure, 2x contamination at heat-exchanger (→2x cleaning/year)**
- **Problem with circulator temperature compensation system (acquire new system)**

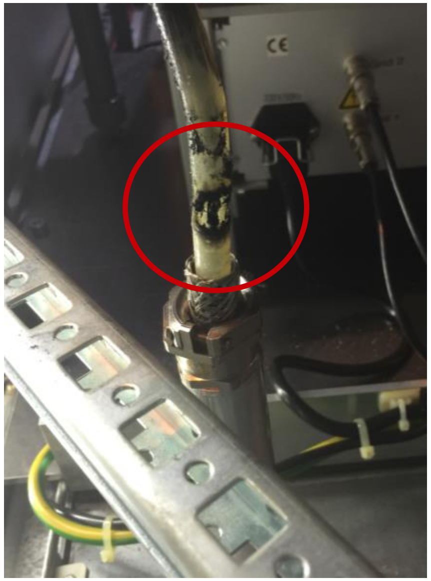
Operation Statistics 2016



Per 13.11.2016

- **Failures at LINAC: Broken HV cable, power supply of SPB**
- **Failures at storage-ring: focus power supply, reflected power interlocks, phase-shifter, HOMFS blocked, main-switch, vacuum interlock.**
- **Problems with S3HC: helium leak at compressor valve (+ on 14.11. Compressor failure)**

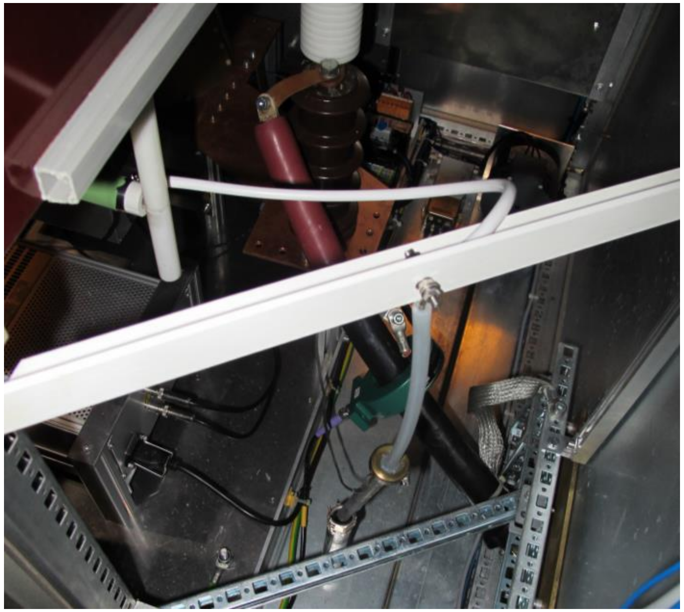
Burnt High Voltage Cable in the LINAC-PFN



←Discharges in the cable

←Triggered the smoke detektor and CO_2 extinguisher

❑Plan to try without corona protection and semiconductive rubber instead ↑



✓New cabling avoids bent HV-cable →

Courtesy of D. Kunz

PAUL SCHERRER INSTITUT

Other SLS RF Works & Outlook

Accomplished:

✓Replaced the last storage-ring cavity in January 2016

✓Capacitors replaced at PSM HV modules of four 500MHz RF-plants (Klystron HV power supply)

✓Replaced capacitors of LINAC klystron focus power supplies and LINAC solenoid power supplies

✓Installed new type of cathode in LINAC: (YU-171 was replaced by Y-845)

✓Replaced 500MHz waveguide directional coupler (solved problem with reflected power interlocks)

✓Arc-Detectors: Coincident detection system implemented. (Radiation hard fibres tested for AFT.)

Work in progress:

❑Improve PLC and Interface of S3HC (with AirLiquide in Jan. 2017 shutdown)

❑Install fire detectors for storage-ring klystron power supplies (Jan. 2017 shutdown)

❑Refurbish Klystrons at CPI

❑Replace capacitors of storage ring klystron power supplies (PSM HV-Modules) (last set in Jan. 2017)

❑Improve HOMFS (with brakes)

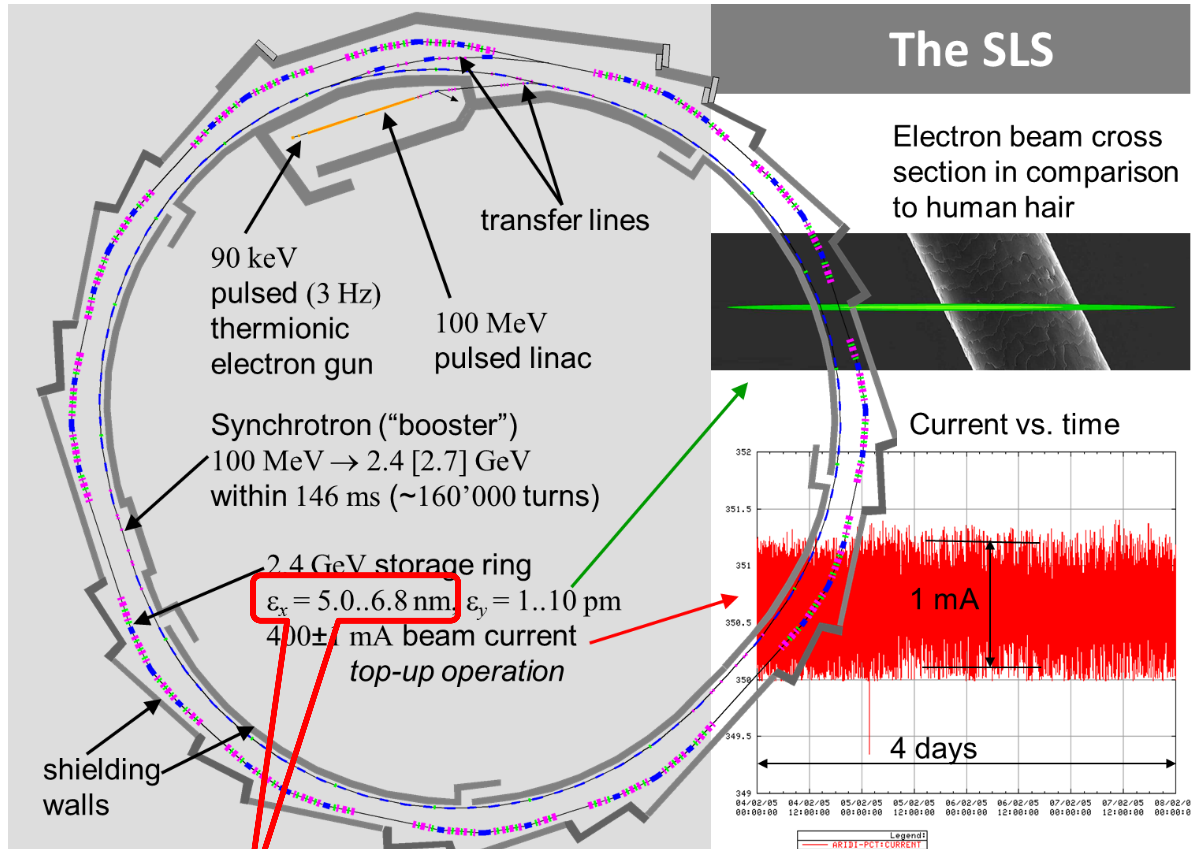
❑Replace Circulator TCUs

❑ Install water valves at LINAC windows and loads (close in case of water leak to vacuum)

Swiss Light Source (SLS)

- 12 TBA cells
- Top-up operation
- Ultra-low vertical emittance: 0.9 ± 0.4 pm
- 4 NC 500 MHz cavities + 4 passive SC 1.5GHz cavities
- Brief history of SLS:

	1990	First ideas for a **Swiss Light Source**
	1993	Conceptual **Design** Report
June	1997	**Approval** by Swiss Government
June	1999	Finalization of **Building**
Dec.	2000	First **Stored Beam**
June	2001	Design current **400 mA** reached **Top up** operation started
July	2001	First **experiments**
Jan.	2005	**Laser beam slicing "FEMTO"**
May	2006	**3 Tesla super bends**
	2010	**~completion: 18 beamlines**



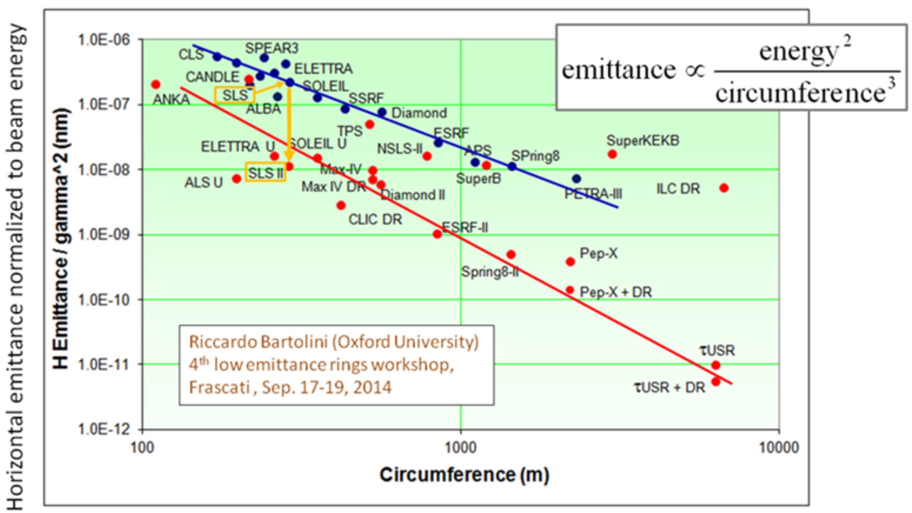
Courtesy of A. Streun

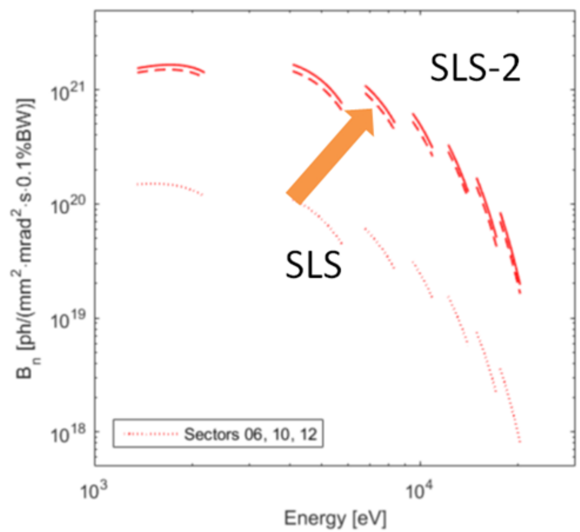
Reduce further

→ diffraction limit → SLS2

SLS-2: Goals and Constraints

- Goals
  - Factor 20~50 lower emittance (5 nm → 100~250 pm)
  - Operation parameters as in the present SLS:
    Energy = 2.4 GeV, Current = 400 mA (top-up), Stability = 1 μm, etc.
- Constraints
  - Reuse the building → Storage ring circum. = 288 m ☹ (3BA→7BA is not enough)
  - Reuse the injector chain (Gun, Linac and Booster) → ε @ 2.4 GeV < 10 nm ☺





Courtesy of M. Aiba

PAUL SCHERRER INSTITUT PSI

SLS2 Lattices under investigation

Needs modification of walls and beam-lines↓

Name	**SLS**	**SLS P3 (db02l)**	**SLS P12(dc12c)**
status	*operating*	*proposed*	*proposed*
Periodicity	3	3	12
Emittance (rad.) [pm]	5022	137	138
Lattice type	TBA	LGB/AB 7BA	LGB/AB 7BA
Curcumference [m]	288	288	290.4
Working Point $Q_{x,y}$	20.42, 8.74	37.38, 10.28	37.22, 10.36
Nat. Chromaticity $C_{x,y}$	-67.0, -19.8	-64.9, -34.5	-66.6, -40.6
Momentum Compaction	6.56×10^{-4}	-1.41×10^{-4}	-1.36×10^{-4}
Radiated Power	205 kW	232 kW	232 kW
RMS Energy Spread	0.86×10^{-3}	1.03×10^{-3}	1.03×10^{-3}
RMS Bunch Length (no 3HC)	3.73 mm	2.72 mm	2.60 mm
Damping times (x,y,z) (ms)	9.0, 9.0, 4.5	4.5, 8.0, 6.6	4.6, 8.2, 6.6

Courtesy of M. Ehrlichman and A. Streun

Option for negative chromaticity↑ and good dynamic apperture

RF frequency

RF frequency	Low (e.g., 100 MHz)	High (e.g., 500 MHz)
Bunch length	Long	Short
Required single-bunch current	High	Low
Frequencies of HOMs	Low	High
Status	Need completely new system (cavity, waveguide, RF amplifier, control, etc.)	Reusing the existing system
Injection scheme	Both transverse injection and longitudinal injection are possible;	Transverse injection

Microwave Instability --- “dc02l” Lattice

Using 1% increase of the energy spread as the threshold

Microwave instability threshold with consideration of RW wake in *db02l*

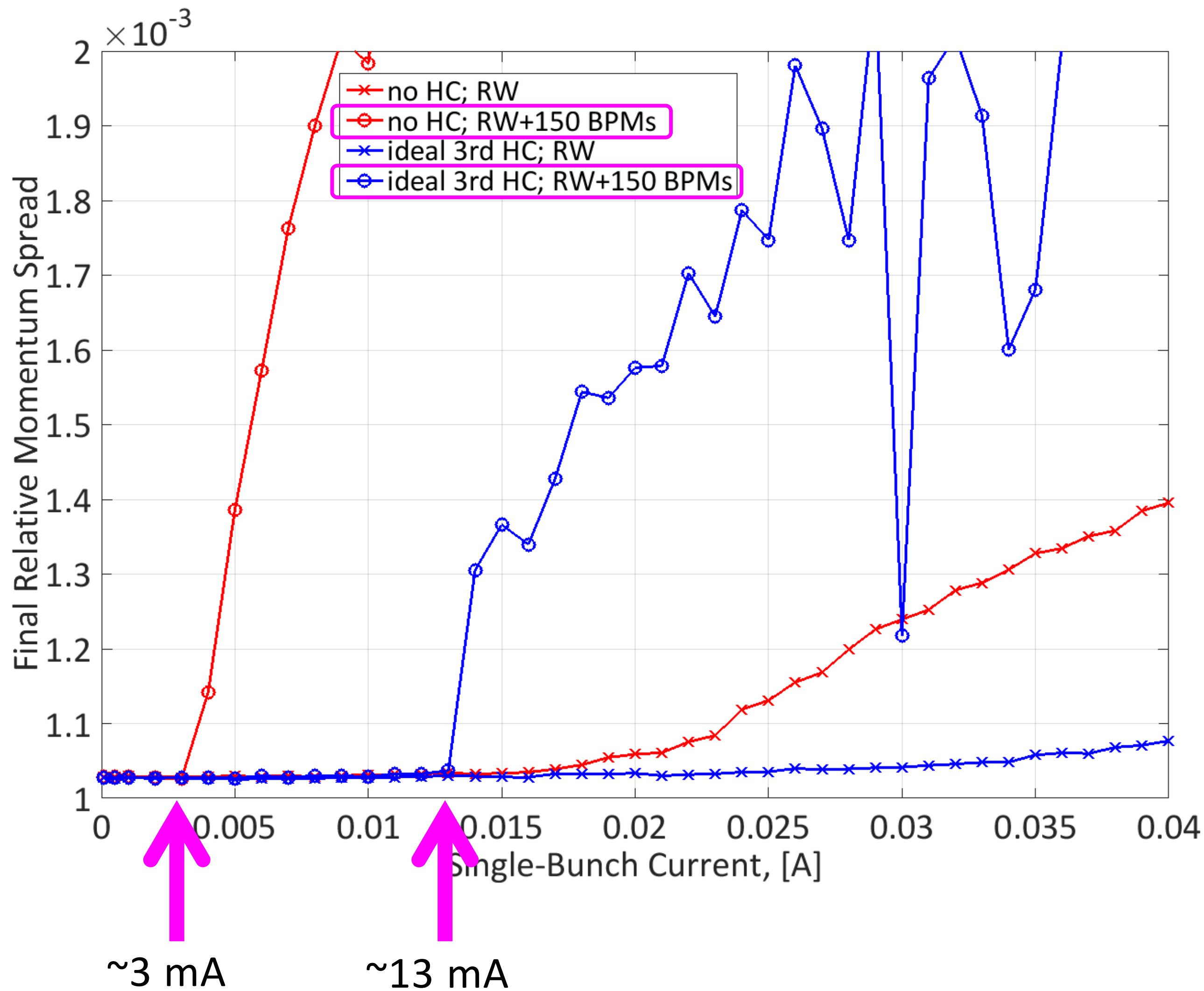
		Round Chamber with inner radius = 10 mm	**Threshold Current**
100 MHz RF	**without harmonic cavity**	Aluminium chamber without coating	16.9 mA
		Copper chamber without coating	19.8 mA
		Stainless Steel chamber without coating	5.92 mA
100 MHz RF	**With ideal 3rd harmonic cavity**	Aluminium chamber without coating	35.2 mA
		Copper chamber without coating	42.8 mA
		Stainless Steel chamber without coating	10.3 mA
500 MHz RF	**without harmonic cavity**	Aluminium chamber without coating	14.0 mA
		Copper chamber without coating	16.7 mA
		Stainless Steel chamber without coating	3.35 mA
500 MHz RF	**With ideal 3rd harmonic cavity**	Aluminium chamber without coating	18.3 mA
		Copper chamber without coating	22.8 mA
		Stainless Steel chamber without coating	7.08 mA

- **The 3rd harmonic cavity in bunch lengthening mode help increase the microwave instability threshold;**
- **Using copper chamber, the resistive-wall impedance is not a limiting factor even using 500 MHz cavity;**

Microwave Instability --- “dc12c” Lattice

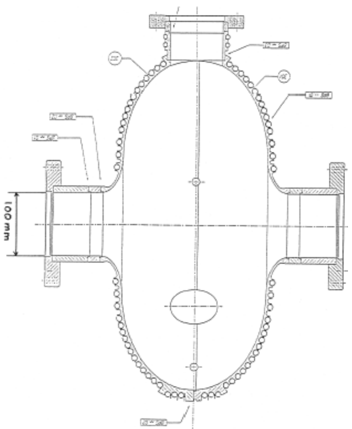
- Longitudinal Short Range Wake: Longitudinal RW + 150 BPMs (first design);
- RF frequency: 500 MHz;
- Peak RF voltage: 1.40 MV
- Vacuum chamber: 10 mm round chamber made of copper;
- The Design Current: 400 mA
  - @ 500 MHz RF, uniform filling pattern, I_b = **0.83 mA (5.0×10^9 e/bunch)**
  - @ 500 MHz RF, 390 normal bunches + 1 ‘camshaft’, $I_{normal} \approx$ **1.01 mA (6.0×10^9 e/bunch)**, $I_{camshaft} \approx$ **4 mA (2.4×10^{10} e/bunch)**
- Simulations are carried out by *mbtrack*.

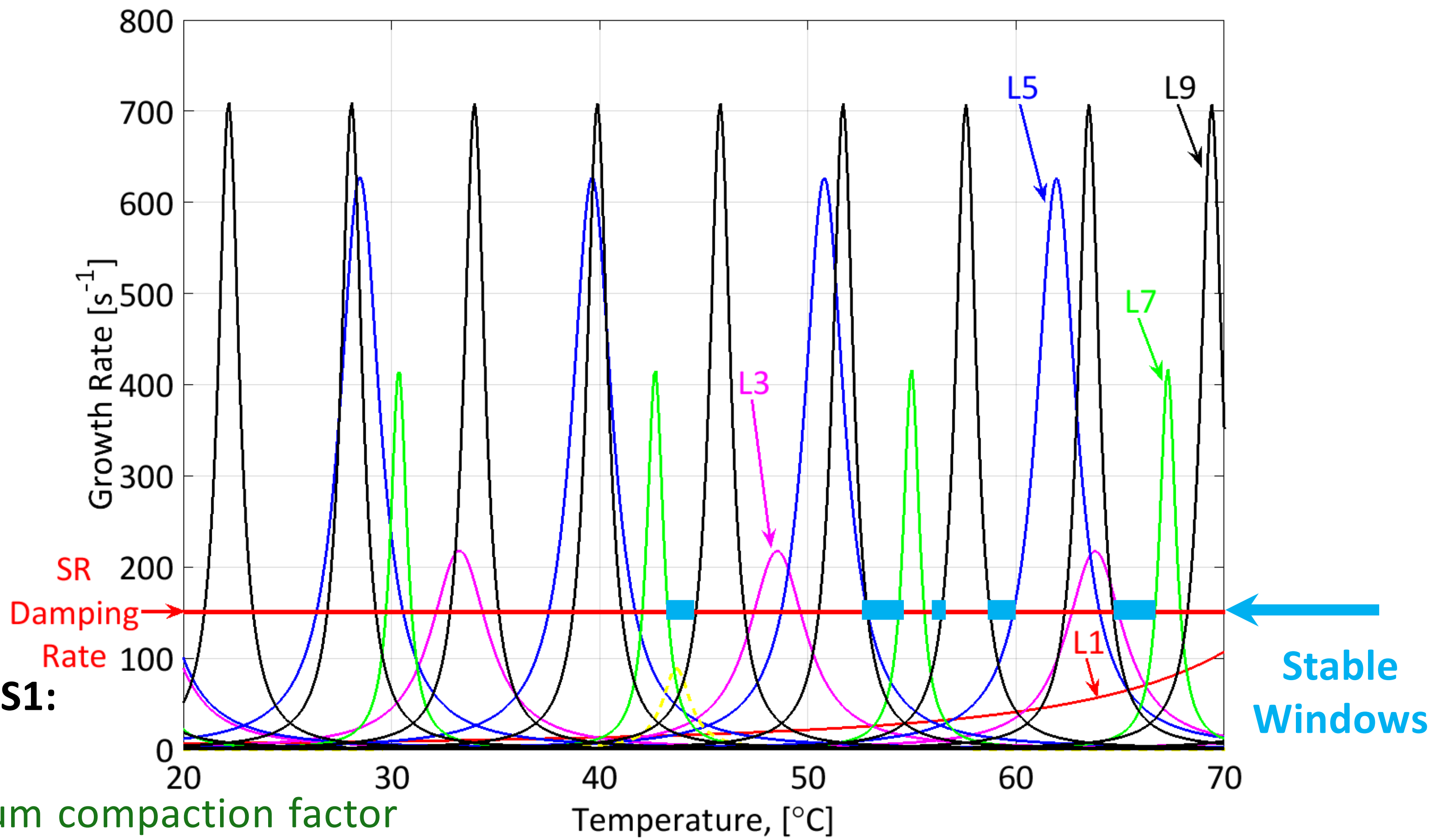
Microwave Instability --- "dc12c" Lattice



Longitudinal Coupled-Bunch Instability --- "dc12c" Lattice

- HOMs of ELETTRA-type 500 MHz cavity used in SLS;





Compared to SLS1:

Lower damping

Lower momentum compaction factor

Lower Synchrotron Tune

Stronger beam loading

Summary & Discussion

- Microwave instability is studied using different RF settings.
  - There is no show-stopper to use the existing 500 MHz RF cavity + 1.5 GHz harmonic cavity;
- The study of longitudinal coupled-bunch instability is ongoing.
- The *mbtrack* code has been transferred to GPU platform (CUDA based, at the moment). The GPU version of *mbtrack* provides the possibility of simulating the coupled-bunch instability in a standalone workstation with a scientific graphic card.
- On-going studies:
  - A more complete impedance budget;
  - Transient effect due the non-uniform filling;
  - Simulations of the longitudinal coupled-bunch instability;

Acknowledgement

- The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement n.º290605 (PSI-FELLOW / COFUND).
- We thank Andreas Adelmann and Uldis Locans for the development of the GPU version *mbtrack*.
- We thank Ryutaro Nagaoka and Francis Cullinan for their kind discussion on the *mbtrack* code.
- We thank people of the SLS2 team.