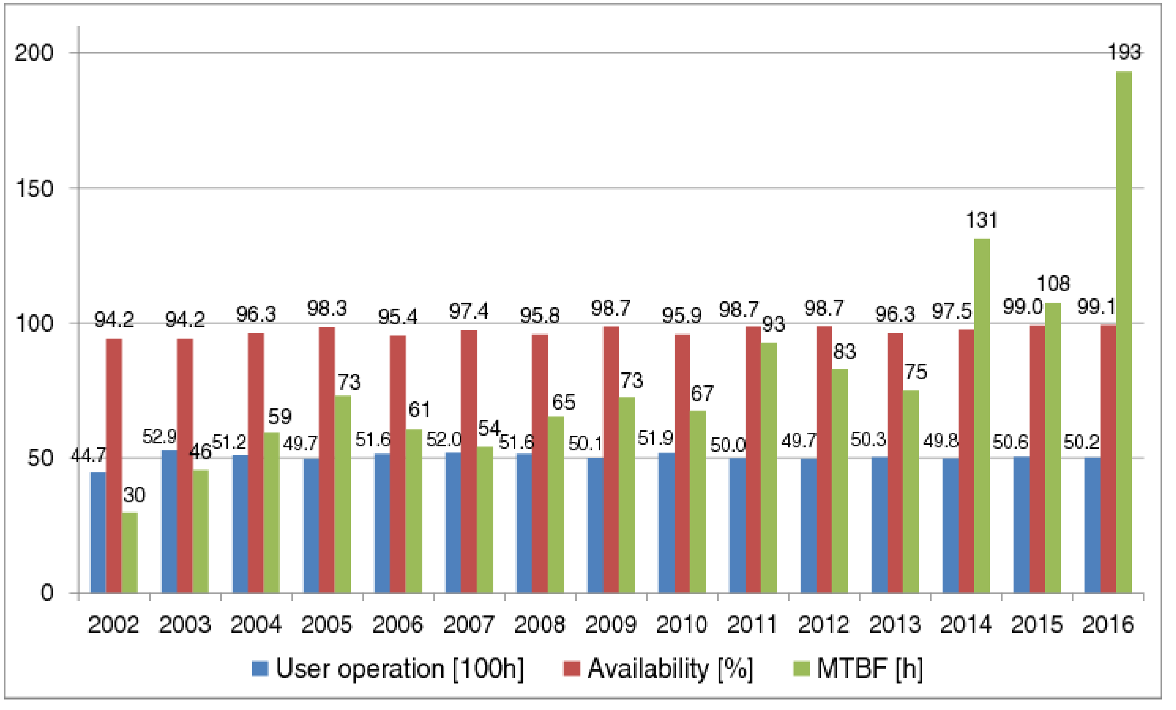
Lukas Stingelin :: Group RF-Systems :: Paul Scherrer Institut

SLS RF operation and status of the SLS-2.0 proposal

21st ESLS-RF Workshop, from 15 November 2017 to 16 November 2017
National Synchrotron Radiation Centre SOLARIS, Kraków

(Updated on 18 December 2017)

SLS Operation

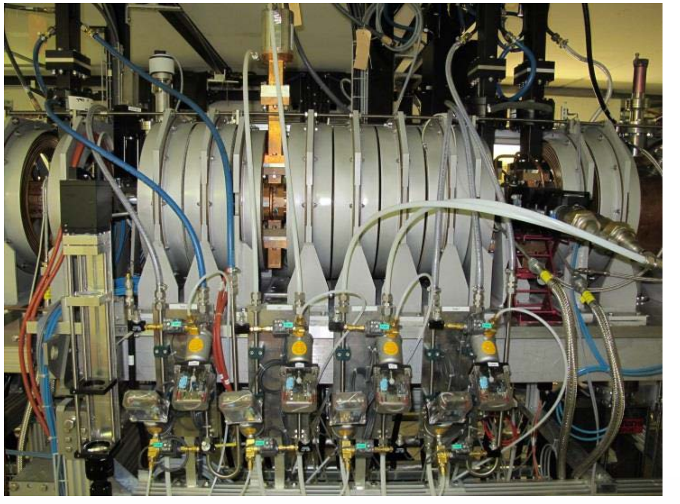


2017: Downtime due to RF: total 7.3h

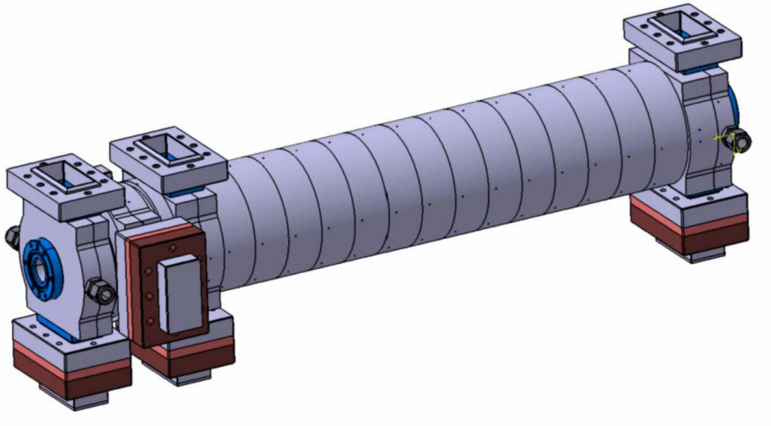
- 2.5h water leak at the booster cavity
  → bypassed and then glued during next shutdown
- 1.5h broken fuse of higher order mode frequency shifter driver PS
- 1.2h vacuum fluctuations newly refurbished klystron
  → cleaned IPS-connector and checked cable

LINAC upgrades

- ✓ HV-cable with semiconducting heat-shrink tube instead of corona protection ring
- ✓ Automatic water valves to close in case of water→vacuum leak installed

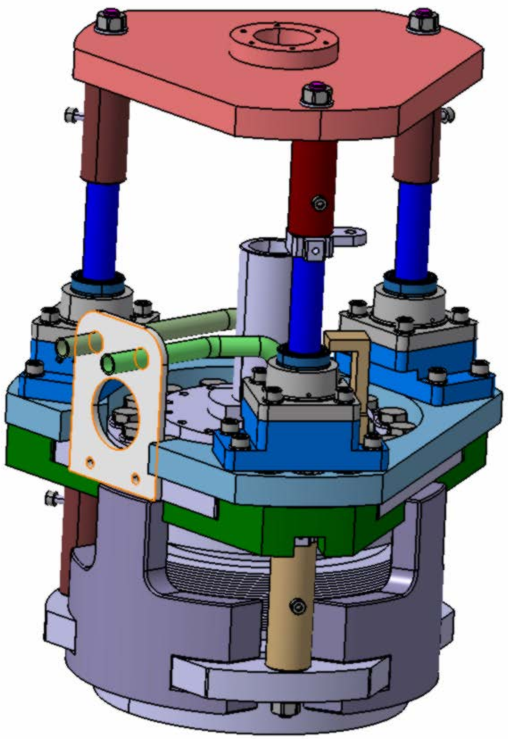


- ❑ Thyratron replacement by solid state switch
- ❑ LLRF-System replacement (similar to SwissFEL)
- ❑ Spare phase shifter and power divider ordered, but delivery delayed
- ❑ Spare structures under investigation



Proposal for a Pre-Finalbuncher spare (Courtesy R. Zennaro & A. Scherer)

Improvement of Higher Order Mode Frequency Shifter



Problems:

- HOMFS was stuck once in 2016
- Plunger is sucked in case of power faillure

Modifications:

- ❑ Glidersystem with ball bearings
- ❑ Electric brakes

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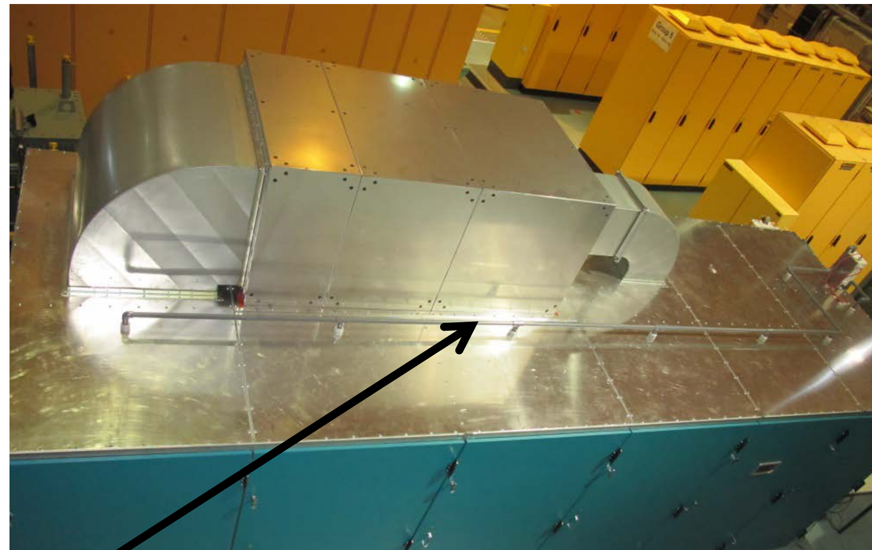
Fire- & Discharge protection for Klystron Supply Unit



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

Maintenance and Upgrades at Booster- and Storage-Ring

- ✓Capacitor replacement of Klystron Supply Units completed
- ✓Circulator Temperature Compensation Units replaced and Parametrized by AFT
- ✓Improved interface to Solid State Amplifier at Booster/Teststand
- ✓Maintenance and repair of water pumps
- ✓Relais of LLRF-System replaced as preventive maintenance

- ❑Spare parts from Ampegon KSU ICS etc. not supported anymore

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SLS2 proposal

Goal: **Upgrade storage ring to provide factor >30 improved emittance + harder X-rays**

For all subsystems such as RF: Upgrade to ensure other 20+ years operation, to optimize operation + maintenance cost, optimize perf. …

Schedule

	2018	2019	2020	2021	2022	2023	2024
SLS-2 preparatory phase							
financing period							
procurement/ testing/pre-assembly							
maximum "dark" period							

- Vacuum chamber with radius 10mm. Previously assumed copper, now 500nm NEG coating (100nm considered not sufficient because of early saturation)
- Request to shift cavities to make space for additional insertion device
- Suggestion to re-evaluate 100MHz option

SLS2 proposal, CDR Lattice

	SLS*)	SLS-2#)
Emittance at 2.4 GeV [pm]	5069	102 → 126♦)
Lattice type	TBA	7BA
Circumference [m]	288.0	290.4
Total *absolute* bending angle	360°	561.6°
Working point $Q_{x/y}$	20.43 / 8.22	39.2 / 15.30
Natural chromaticities $C_{x/y}$	-67.0 / -19.8	-95.0 / -35.2
Optics strain[1)]	7.9	5.6
Horizontal damping Partition J_x	1.00	1.71
Momentum compaction factor [10^{-4}]	6.56	-1.33
Radiated Power [kW] [2)]	208	222
rms energy spread [10^{-3}]	0.86	1.03 → 1.07♦)
damping times x/y/E [ms]	8.9 / 8.9 / 4.4	4.9 / 8.4 / 6.5

1) product of horiz. and vert. normalized chromaticities C/Q

2) assuming 400 mA stored current, bare lattice without IDs

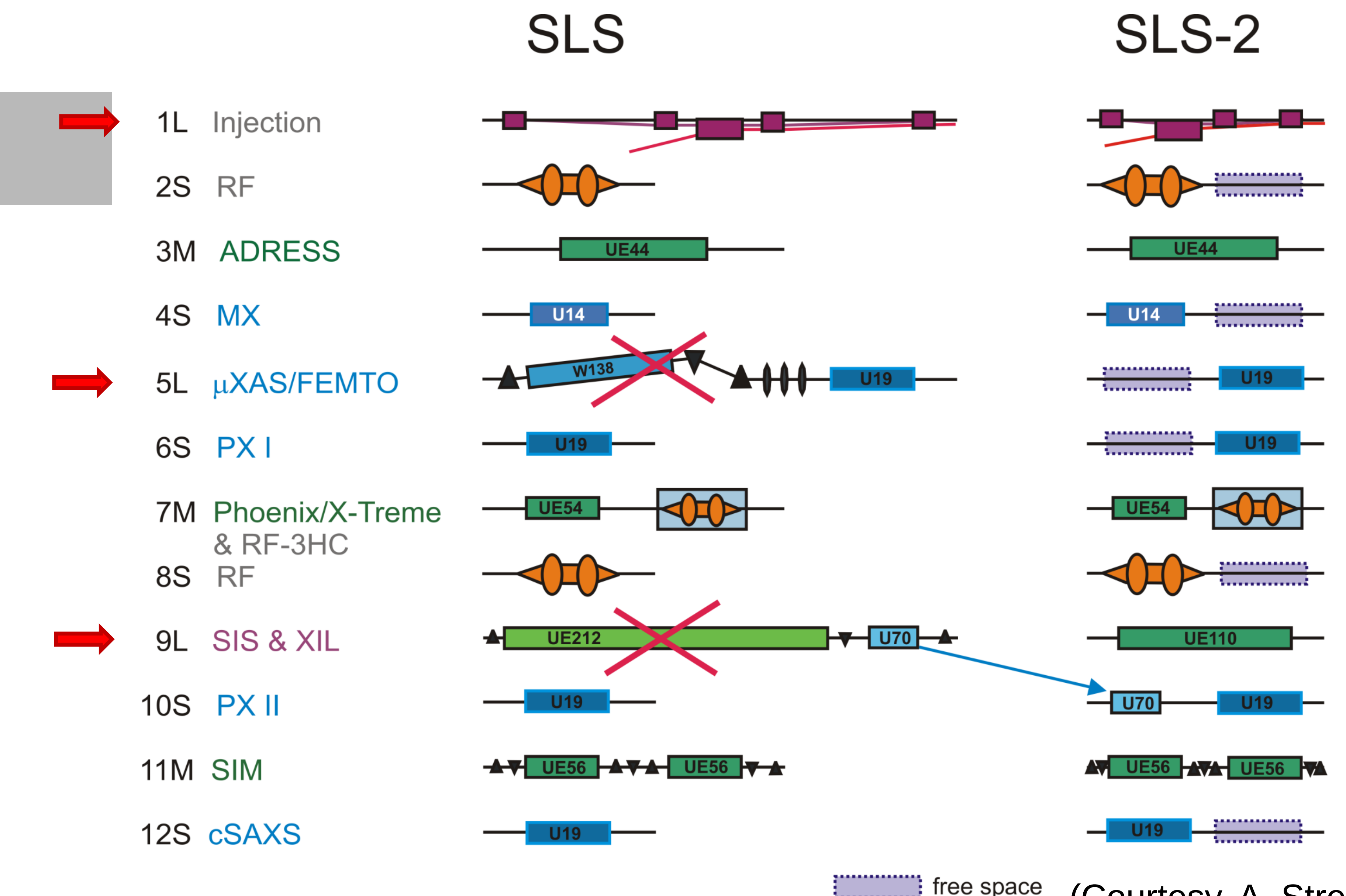
*) SLS lattice before FEMTO installation (<2005)

#) SLS-2 with 3 superbends

♦) including intra-beam scattering for 1 mA bunch current (400 mA in 400 of 484 buckets; 500 MHz), 10 pm vertical emittance, 1.4 MV RF voltage, 3rd harmonic cavity for 2.2×bunch length.

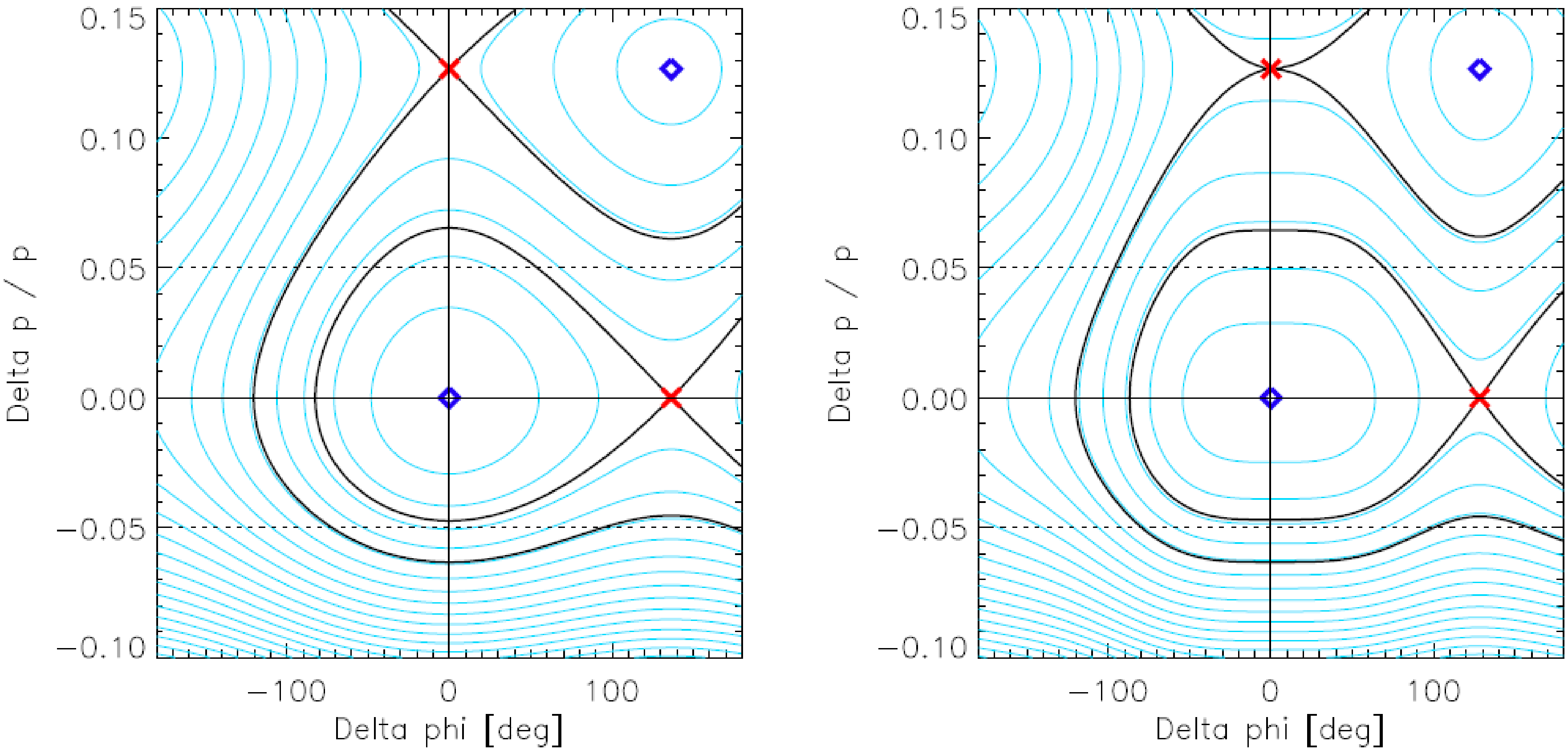
(Courtesy, A. Streun)

Straight sections



(Courtesy, A. Streun)

SLS2-RF bucket

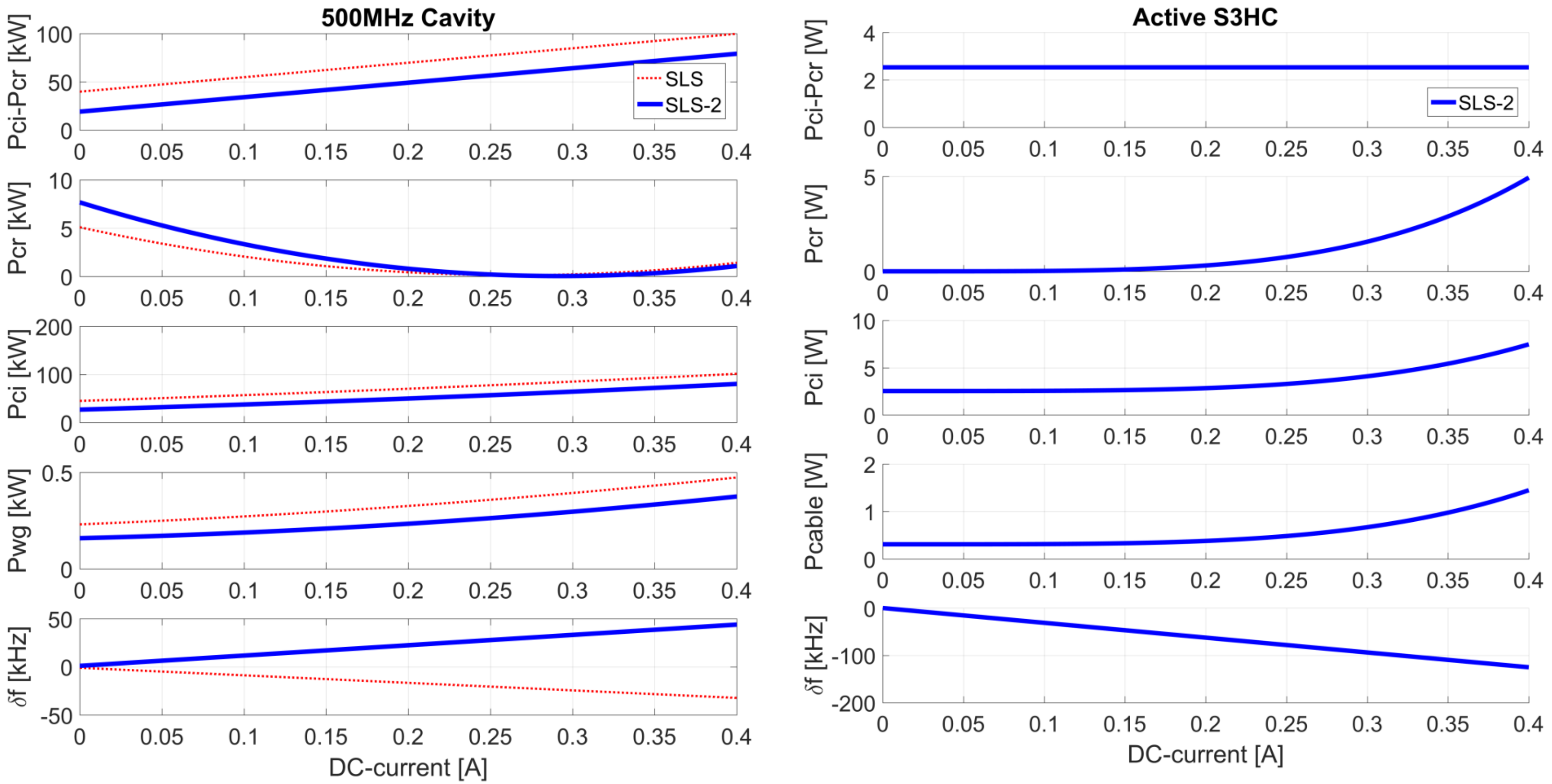


RF bucket for 1.4 MV, 500 MHz, w/o and with 3HC

- small α_1 → transition to “alpha bucket” at 2 MV
- large α_2 → asymmetric momentum acceptance

(Courtesy, A. Streun)

SLS2 vs. SLS1: Power Requirements



- ✓ Relaxed power requirement
- o Negative momentum compaction factor requires opposite de-tuning

Option with driven harmonic cavity? (at 0-crossing to reduce power-requirement)

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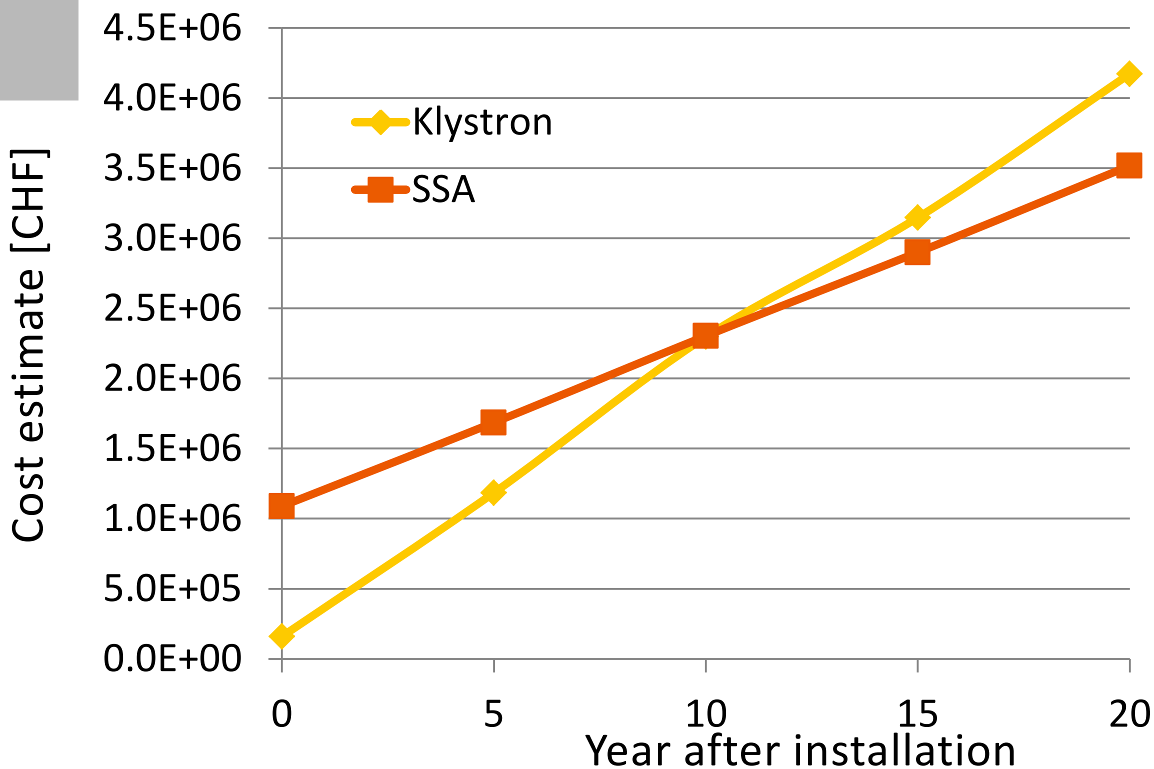
Cost Estimate for 500MHz Klystron vs. Solid State Amplifier (For Discussion)



Assumptions:

- 1 RF-plant with 80kW
- Efficiency Klystron: 40%
- Efficiency SSA: 57%
- Refurbishment after 5 years
- New Klystron after 10 years
- No early Klystron faillure

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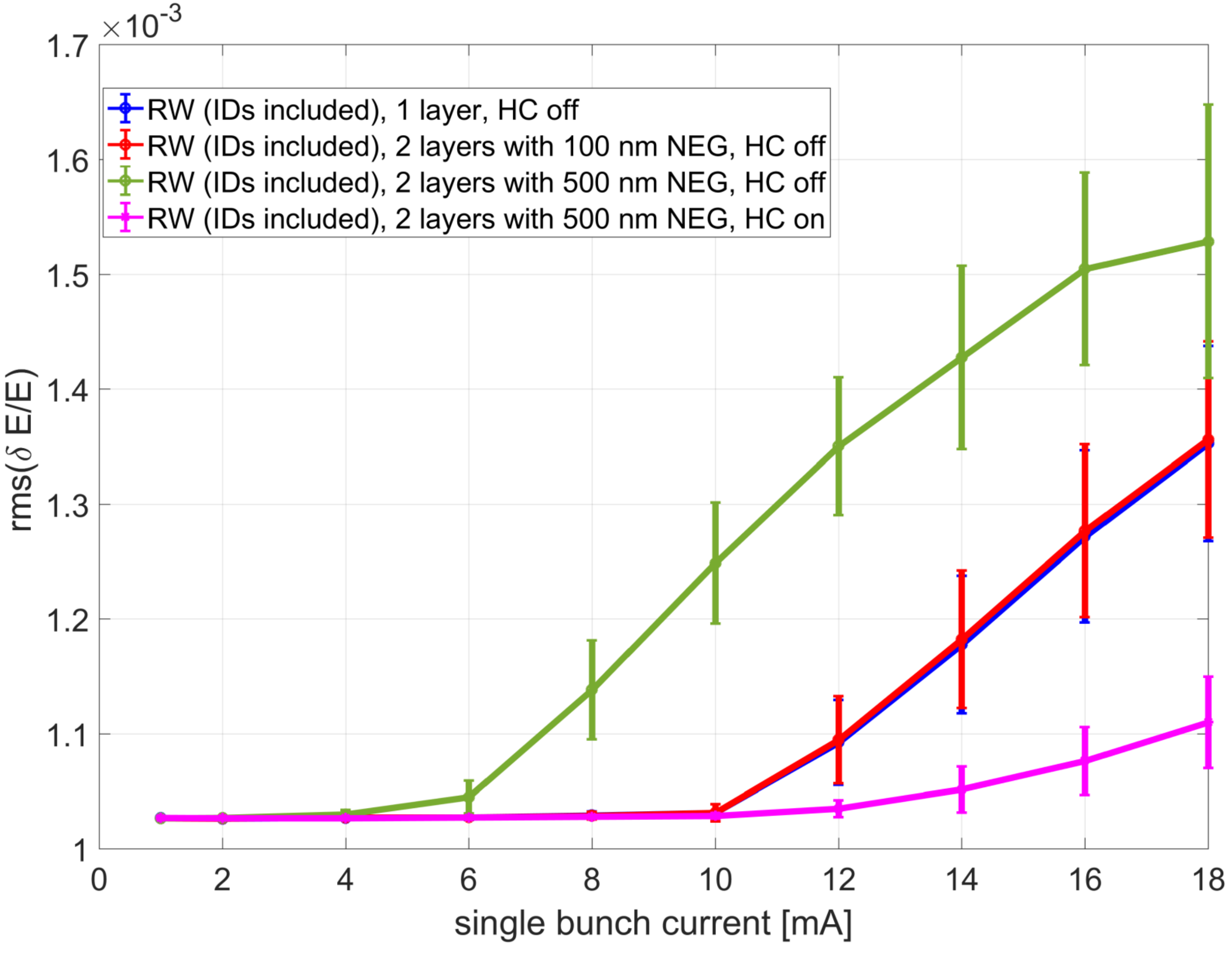
Comparison Chart 500MHz vs. 100MHz (For Discussion)

	500MHz + S3HC	100MHz
Total Main Voltage	1420kV	840kV
Need harmonic cavity	yes	yes
Power requirement per cavity	79kW	67kW
Cost for RF power per year	760kCHF	350kCHF
Need gap in filling pattern	yes	No
Injection	Anti-septum + 3K bump	Longitudinal possible
Single bunch stability	Tight without 3HC	Not without 3HC
Multibunch stability	OK with L9 damper	Many HOMs

Assumptions:

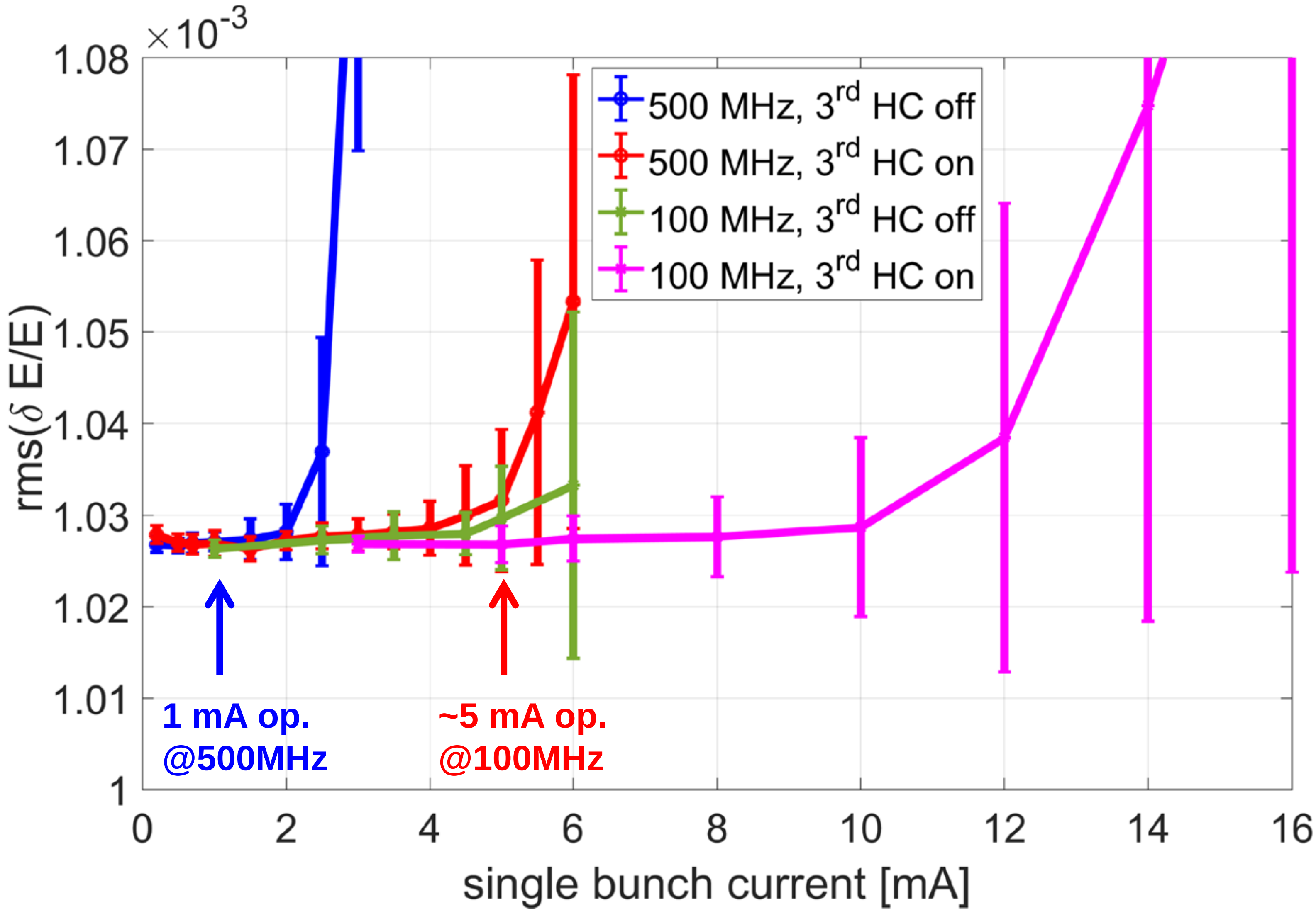
- 5% RF acceptance
- 500MHz system ~ SLS1 (Rsh=3.4MΩ), 40% efficiency + S3HC
  100MHz system ~ MAX IV (Rsh=3.2MΩ), 67% efficiency

Single Bunch Thresholds for 500MHz with NEG (BPMs not considered)



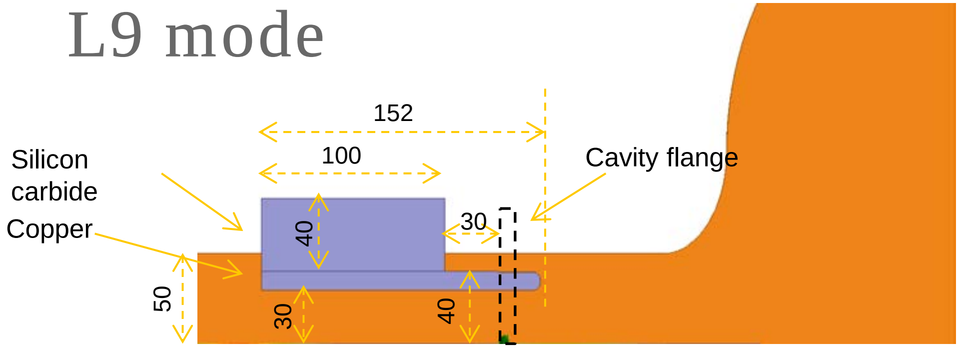
(Courtesy A. Citterio)

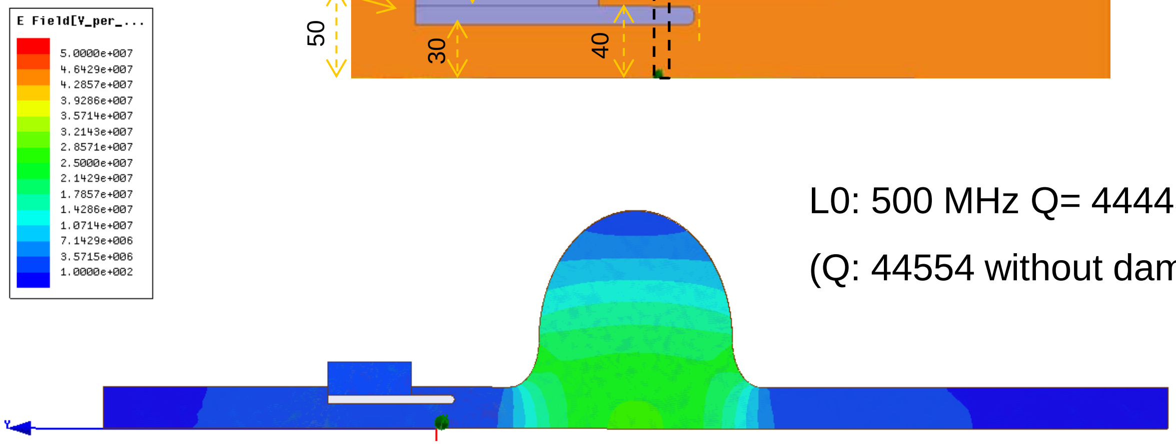
Single Bunch Thresholds, 500MHz vs. 100MHz (Total Impedance)



(Courtesy A. Citterio)

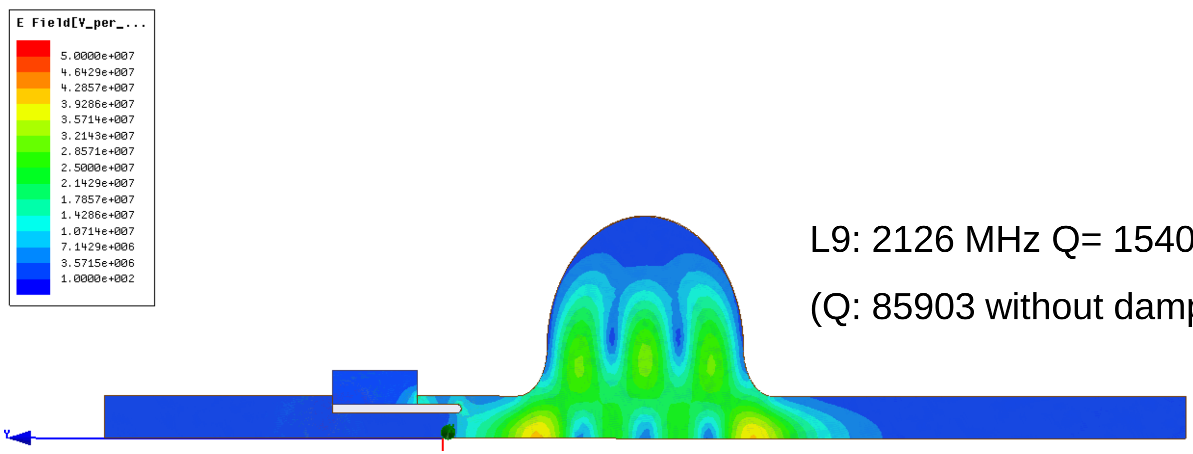
Preliminary study of a damping solution for the L9 mode





L0: 500 MHz Q= 44445; 0.24% P in the load

(Q: 44554 without damping)



L9: 2126 MHz Q= 1540; 98.2% P in the load

(Q: 85903 without damping)

(Courtesy R. Zennaro)

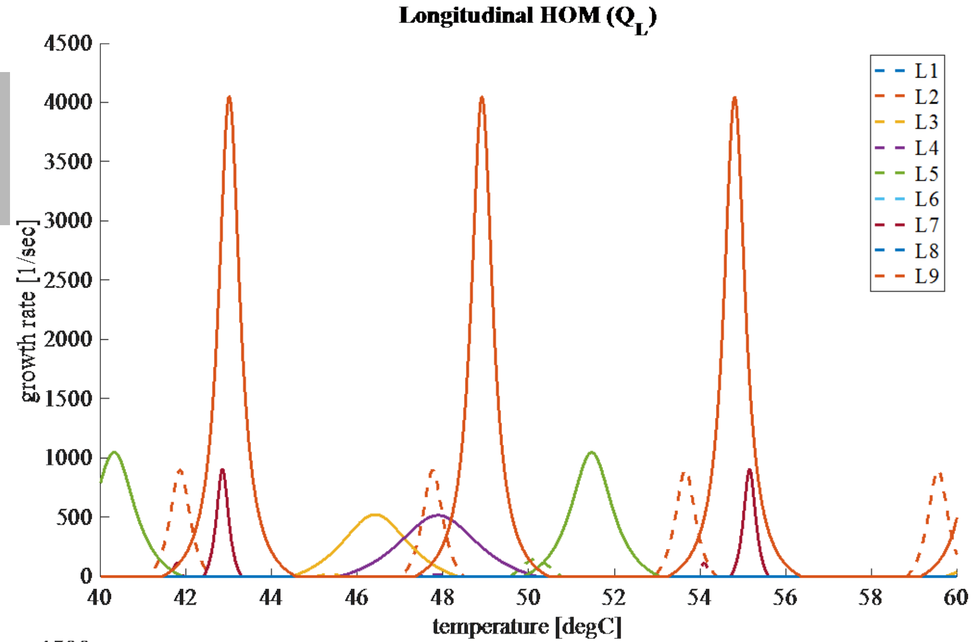
Preliminary study of a damping solution for the L9 mode

Mode	Frequency	Q undamped	Q damped	ΔQ	R/Q	R	R*f
	[MHz]				[Ohm]	[Mohm]	[kOhm*GHz]
L0	500.4	44554	44445	-0.24%	80	3.56	1779.2
L1	946.5	45697	45294	-0.88%	29	1.31	1243.3
L2	1062.4	60764	59214	-2.55%	0.7	0.04	44.0
L3	1420.5	53610	39513	-26.29%	4.8	0.19	269.4
L4	1514.1	62754	62485	-0.43%	5	0.31	473.0
L5	1616.9	74292	33021	-55.55%	8.9	0.29	475.2
L6	1876.7	55443	8222	-85.17%	0.3	0.00	4.6
L7	1948.1	79156	12415	-84.32%	1.6	0.02	38.7
L8	2094.2	62169	1070	-98.28%	0.1	0.00	0.2
L9	2126	85903	1540	-98.20%	7.1	0.01	23.2

Threshold: 31.7 kOhm*GHz

(Courtesy R. Zennaro, P. Craievich)

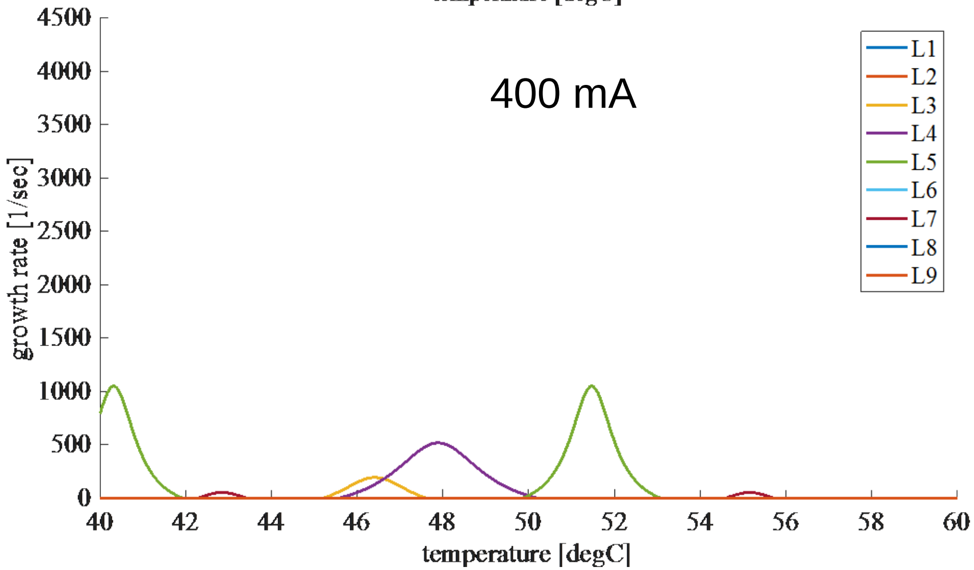
Preliminary study of a damping solution for the L9 mode



Dashed lines - 100mA

Solid lines – 400 mA

No damper, no 3HC



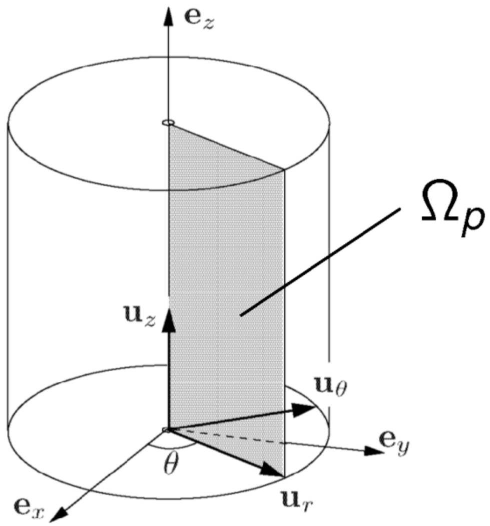
With damper, no 3HC

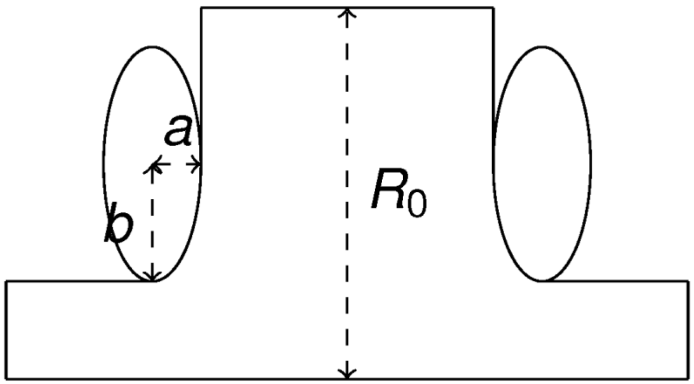
Note: RF parameters of the cavity 1 in SLS

(Courtesy P. Craievich)

Shape optimization in RF structures

- parameterizing the cross section Ω_p[1] of axisymmetric cavities

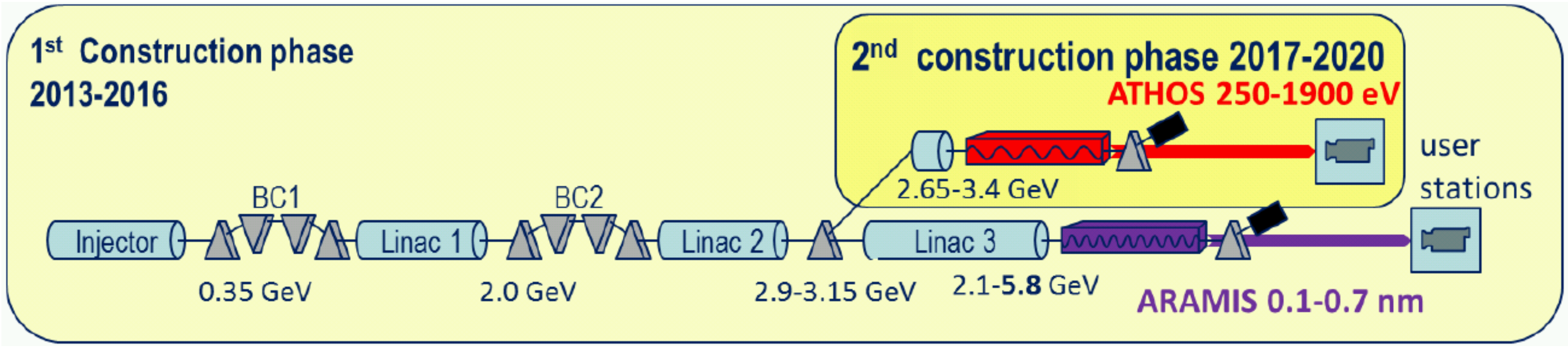




- defining goals, e.g. target frequency, maximizing impedance
- using optimization algorithms to find the parameters of cavity shapes that fulfil the given goals

[1] Sketch taken from Diss. ETH No. 16243.

SwissFEL Project Summary & Outlook



Status (as of Nov. 13 2017)

RF systems installed in technical gallery: 27/34

Beam operation RF conditioning Beam op: 16 Cond: 4 @2.5GeV

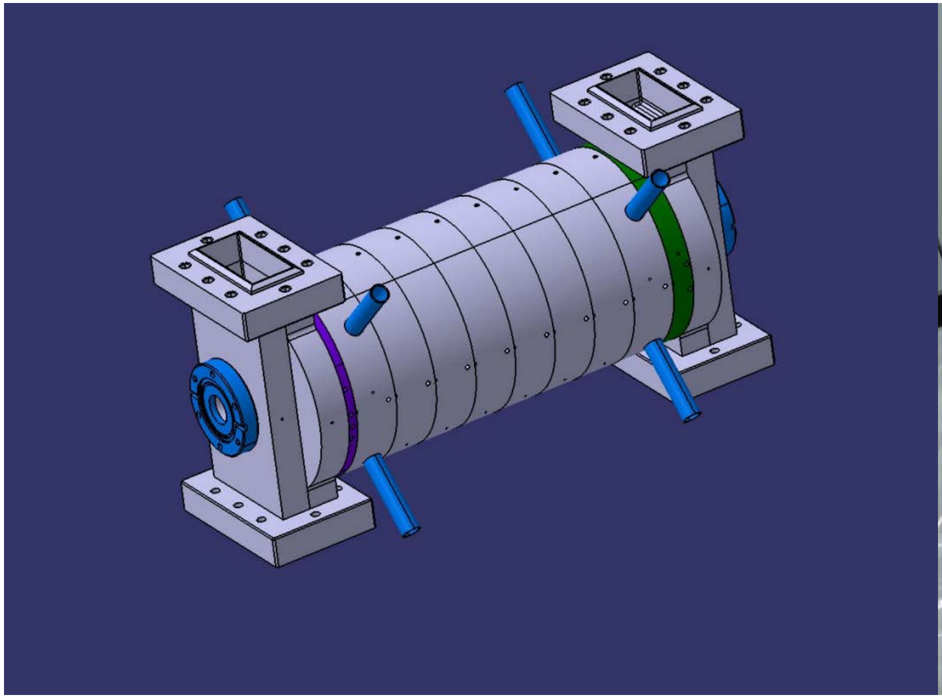
Schedule

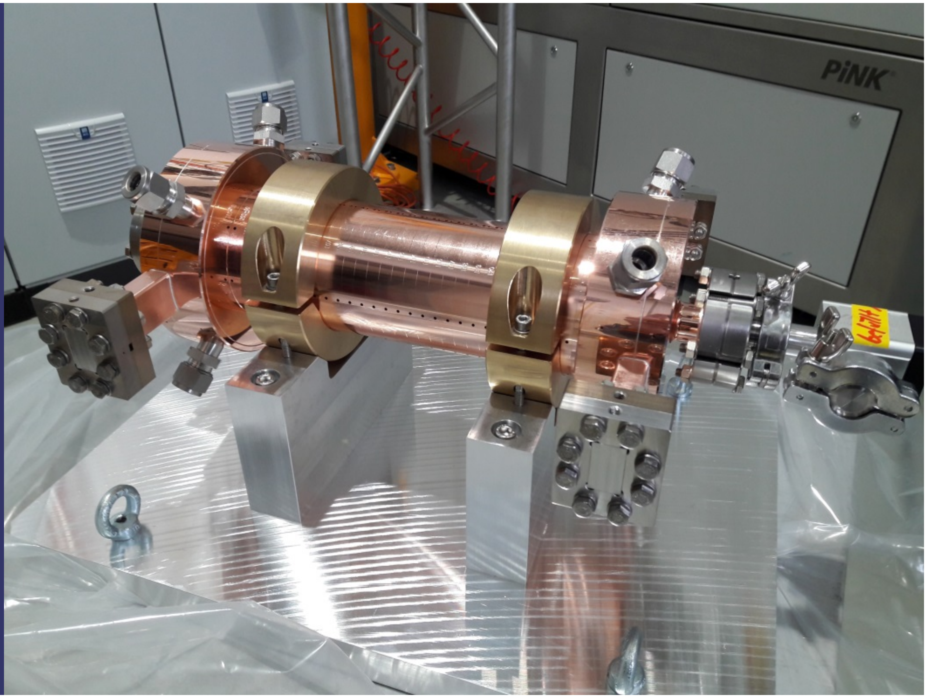
	2017	2018	2019	2020
Aramis	**Pilot experiments**	**Start user operation**		
Athos				
- dual bunch operation		**Dual bunch operation**	**Individual control**	**Individual control**
- RF systems installation & commissioning		**Installation**	**Commissioning**	**RF Operational**
- user operation				**Pilot experiments**

RF-Structure Developments (High Gradient Collaborations ELETTRA & PSI for S-band CERN & PSI for X-band)

S-band

X-band





(Courtesy M. Bopp, R. Zennaro, A. Scherer)

RF-Structure Developments (Collaboration CERN, DESY, PSI for Deflecting Cavity with Variable Polarization)

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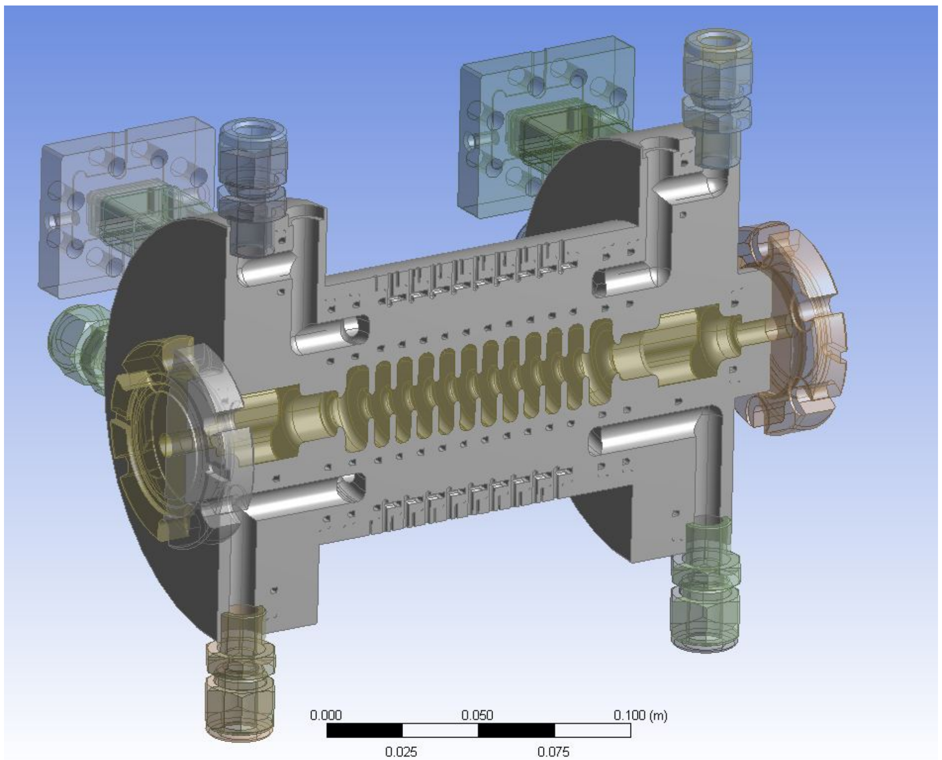
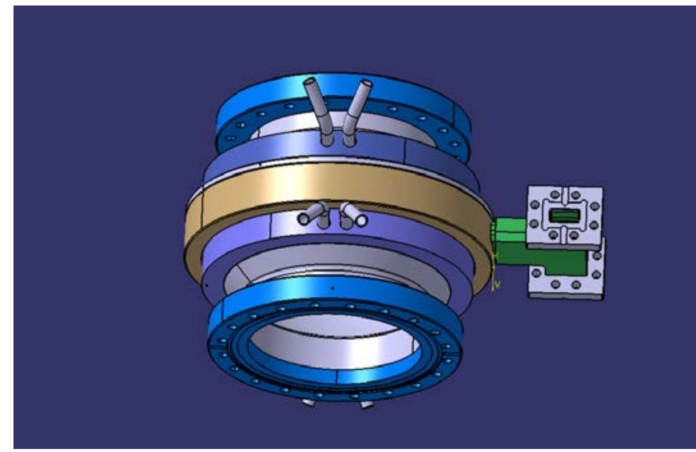
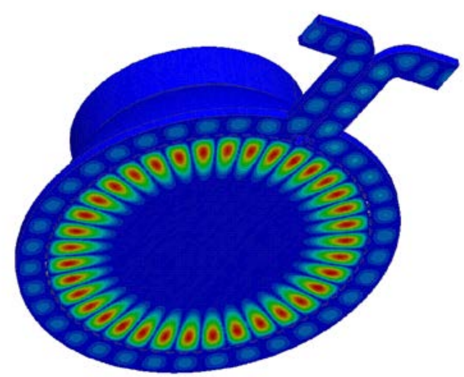
X-band TDS



X-band BOC

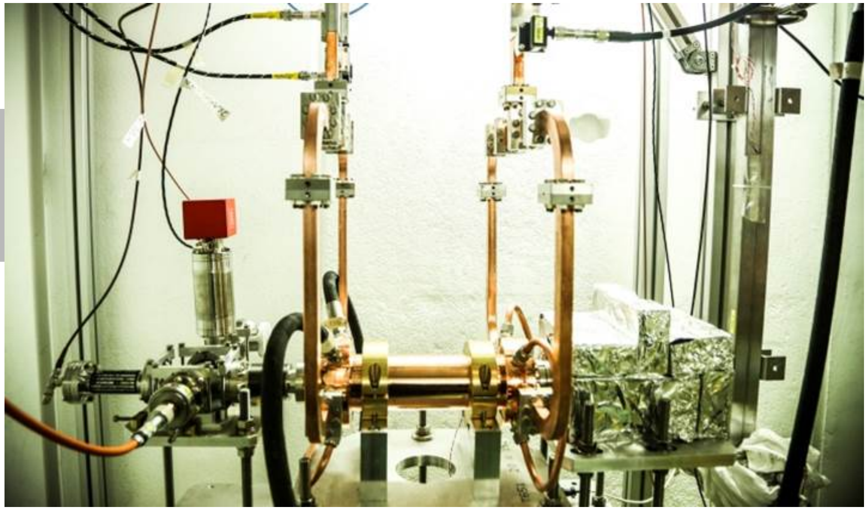




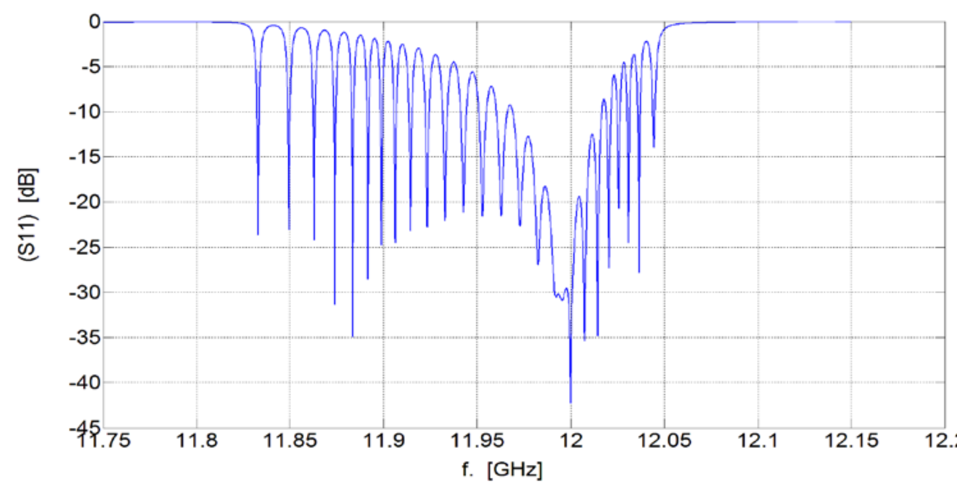
(Courtesy M. Bopp, P. Craievich, R. Zennaro)

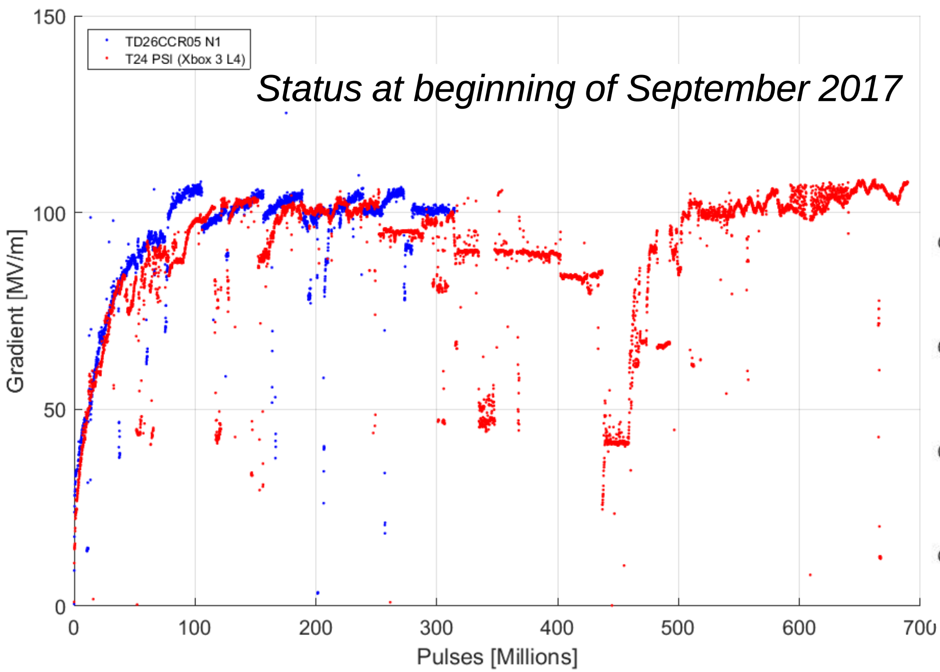
Thanks!

From SwissFEL to CLIC



PSI produced two T24 in collaboration with CERN. These test structures have been produced with the same “recipe” used for SwissFEL. Power test under way in CERN

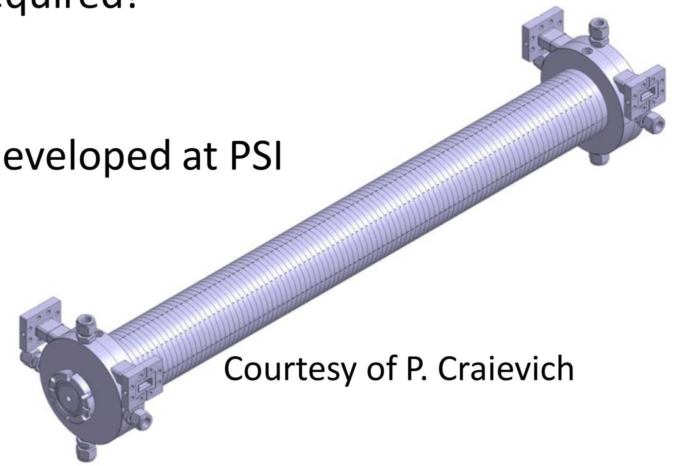




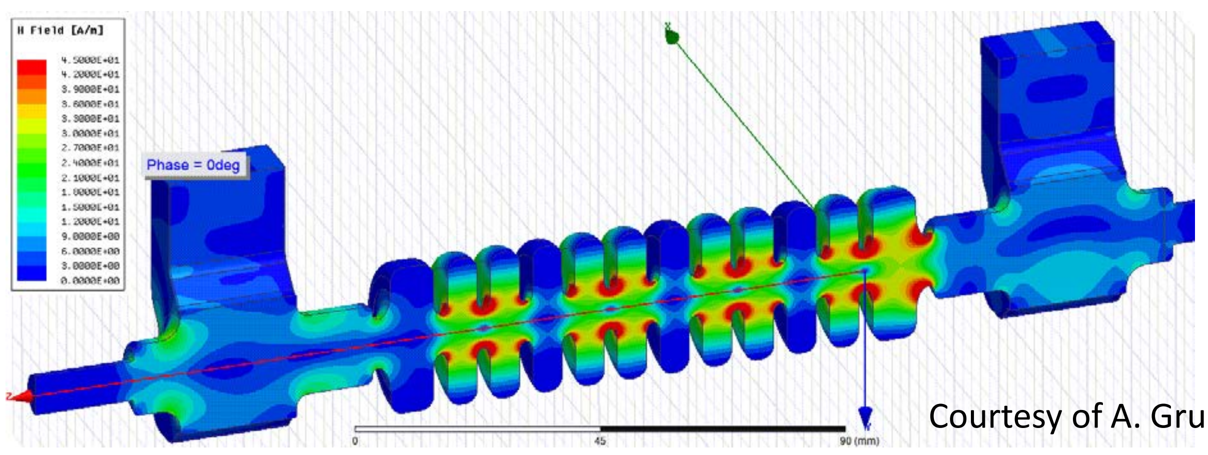
From C-band to X-band

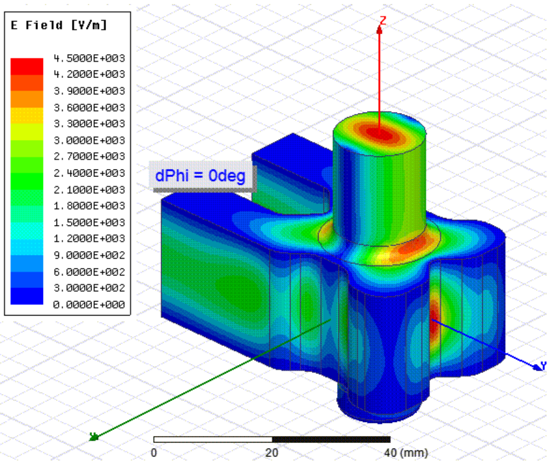
Collaboration for X-band TDS

- ✓TDS with a novel variable polarization feature
- ✓ Tuning may be difficult because a tight symmetry is required!
- ✓RF design by A. Grudiev in CLIC-note-1067 (2016)
- ✓First prototype with tuning-free assembly procedure developed at PSI
- ✓Status: drawings ready



Courtesy of P. Craievich



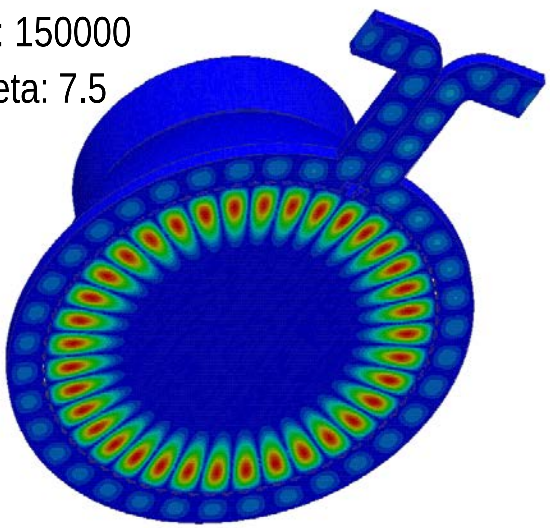


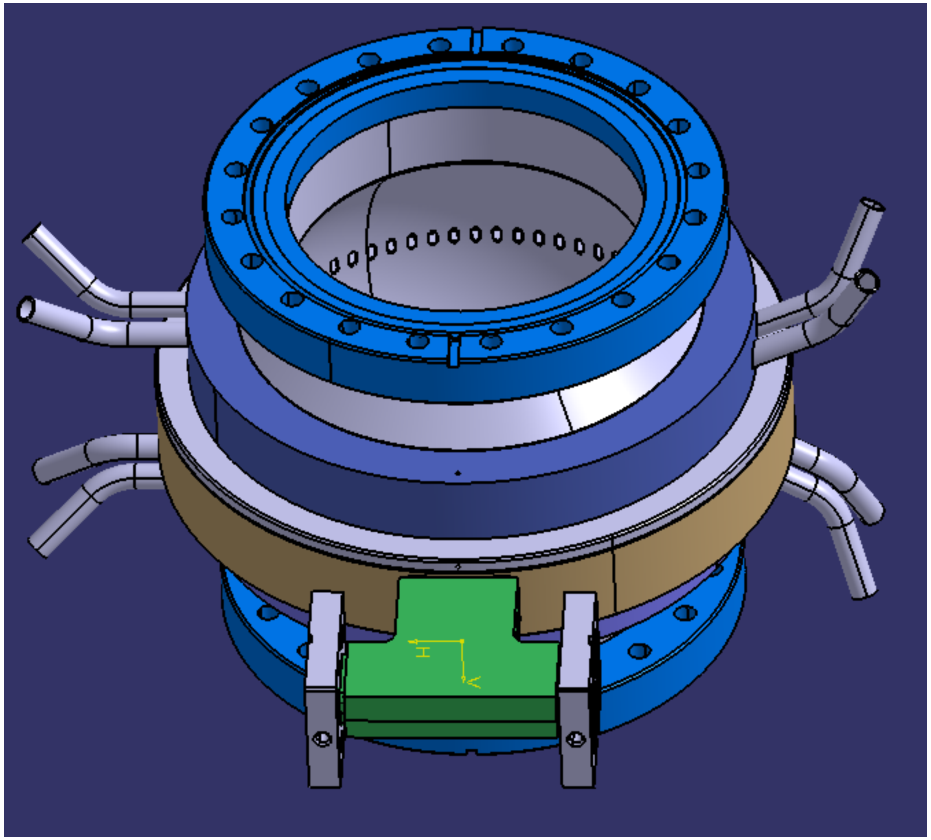
Courtesy of A. Grudiev

From SwissFEL to CLIC

PSI is designing a X-band BOC for the deflecting cavity in SwissFEL.
The design is basically a scaling of the existing C-bend pulse compressor.
This pulse compress could be a component of the CLIC module.
Status: under mechanical design

Operating mode: TM18,1,1
Freq.: 11995.2 MHz
Q: 150000
Beta: 7.5





Courtesy of R. Zennaro