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PSI

Status of the SwissFEL C-band Linac

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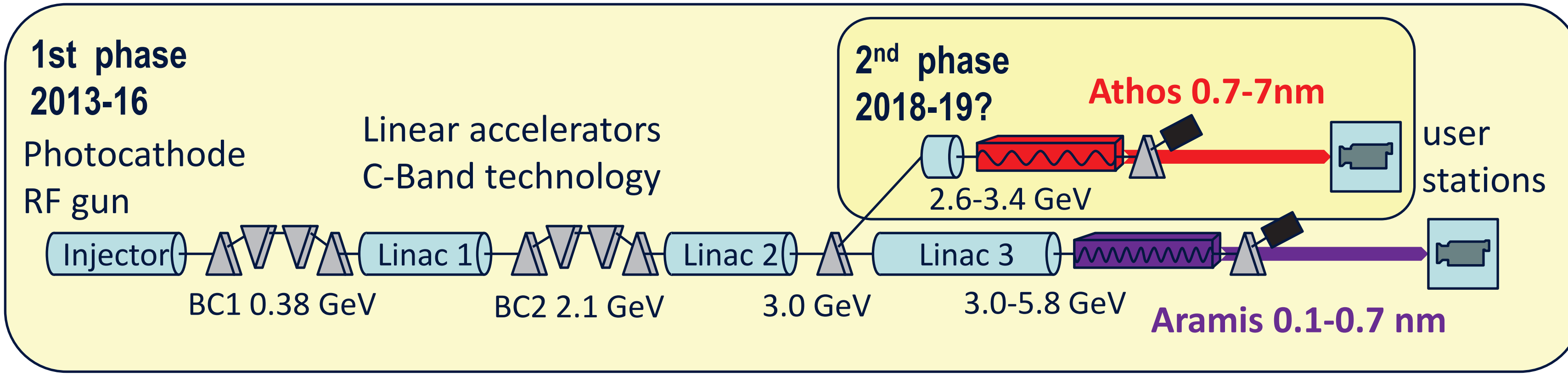
(Paul Scherrer Institute)

The SwissFEL Linac



The SwissFEL Linac:

- Linac 1-3
  - 5.5 GeV acceleration
  - C-band, 28 MV/m, new high shunt impedance structures to minimize overall costs
  - No choke mode required (no bunch trains)
  - Preassembled module with waveguides and pulse compressor to minimize work in tunnel
- Fast switch-yard to distribute bunches between Aramis and Athos (see **MOP039**)
- Bunch compressor BC2
- Transverse deflecting C-band structures

SwissFEL parameters	
Wavelength from	1 Å - 70 Å
Photon energy	0.2-12 keV
Pulse duration	1 fs - 20 fs
e^- Energy	5.8 GeV
e^- Bunch charge	10-200 pC
Repetition rate	100 Hz

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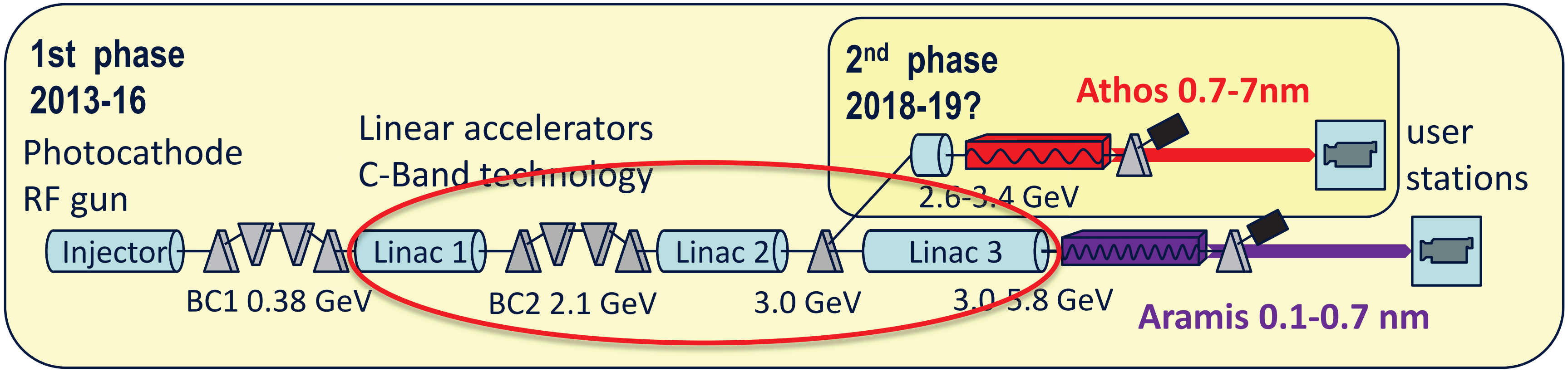

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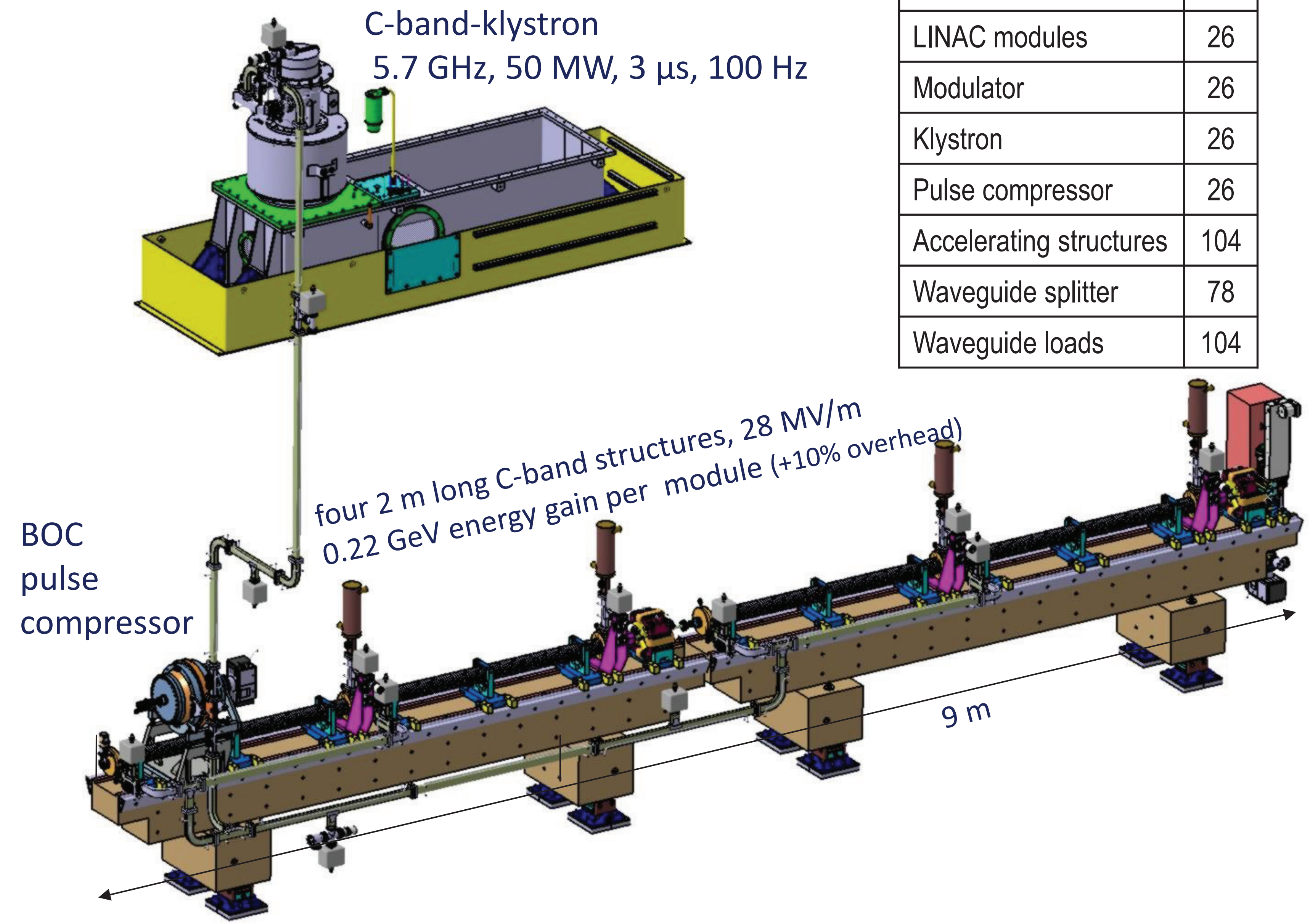
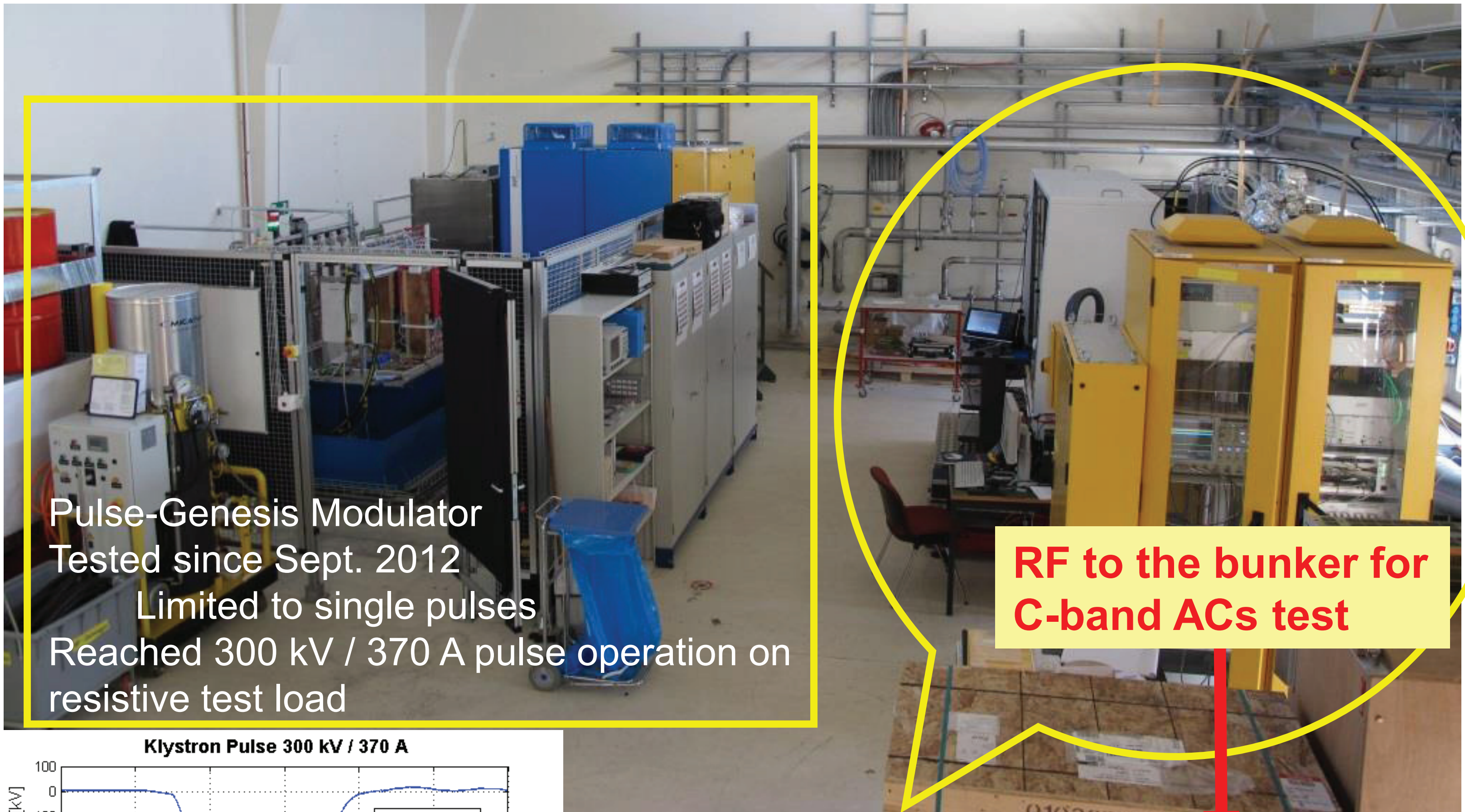
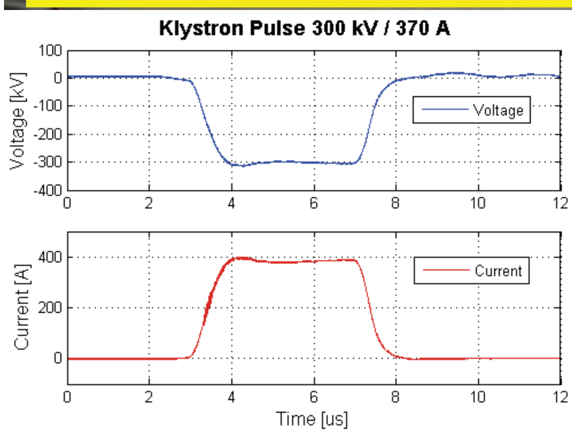
SwissFEL Main Linac building block

Main LINAC	#
LINAC modules	26
Modulator	26
Klystron	26
Pulse compressor	26
Accelerating structures	104
Waveguide splitter	78
Waveguide loads	104



C-Band test stand





ScandiNova K2 Modulator:
In regular use: 24/7 100 Hz operation for tests of waveguide components, pulse compressor and accelerating structures

Modulators are now disassembled to make space for new prototypes.

Prototype modulator ordered from Ampegon

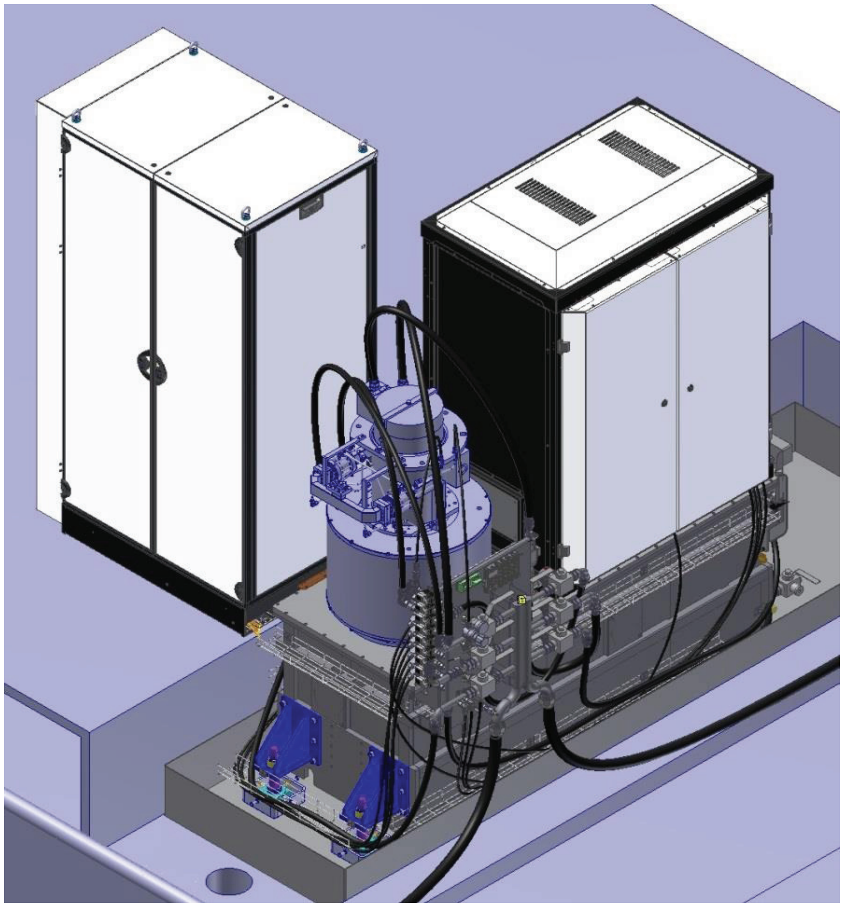
AMPEGON

Type-μ modulator prototype for PSI C-band

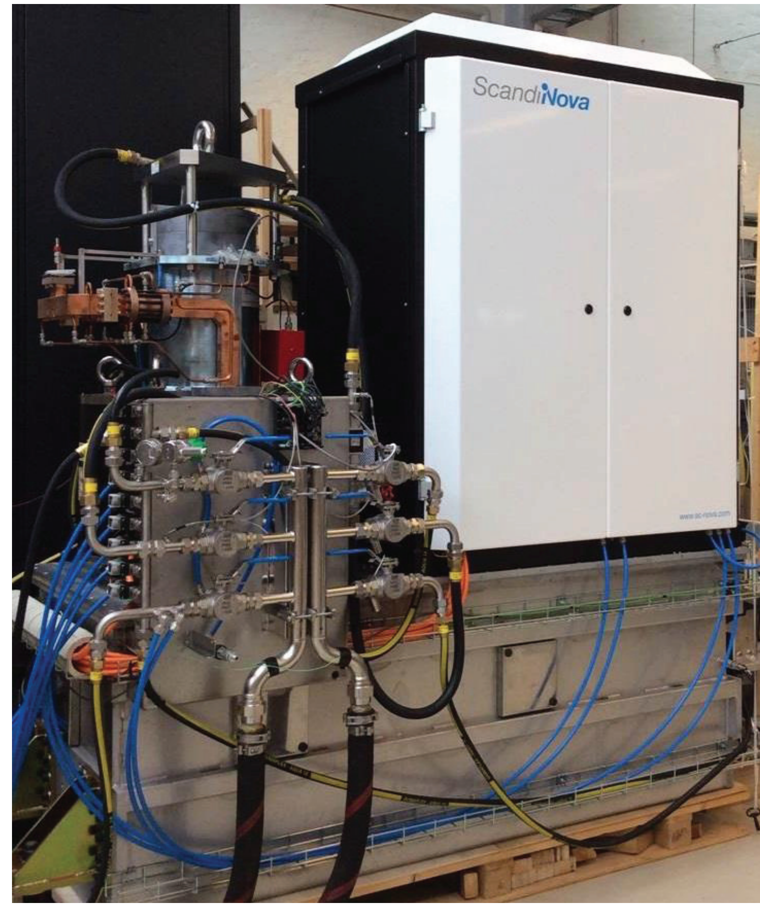
Prototype modulator ordered from Scandinova

ScandiNova

K2-3 for PSI C-band:
50 MW, 370kV / 344A / 3μs / 100 Hz



Design of C-Band K2-3 Modulator



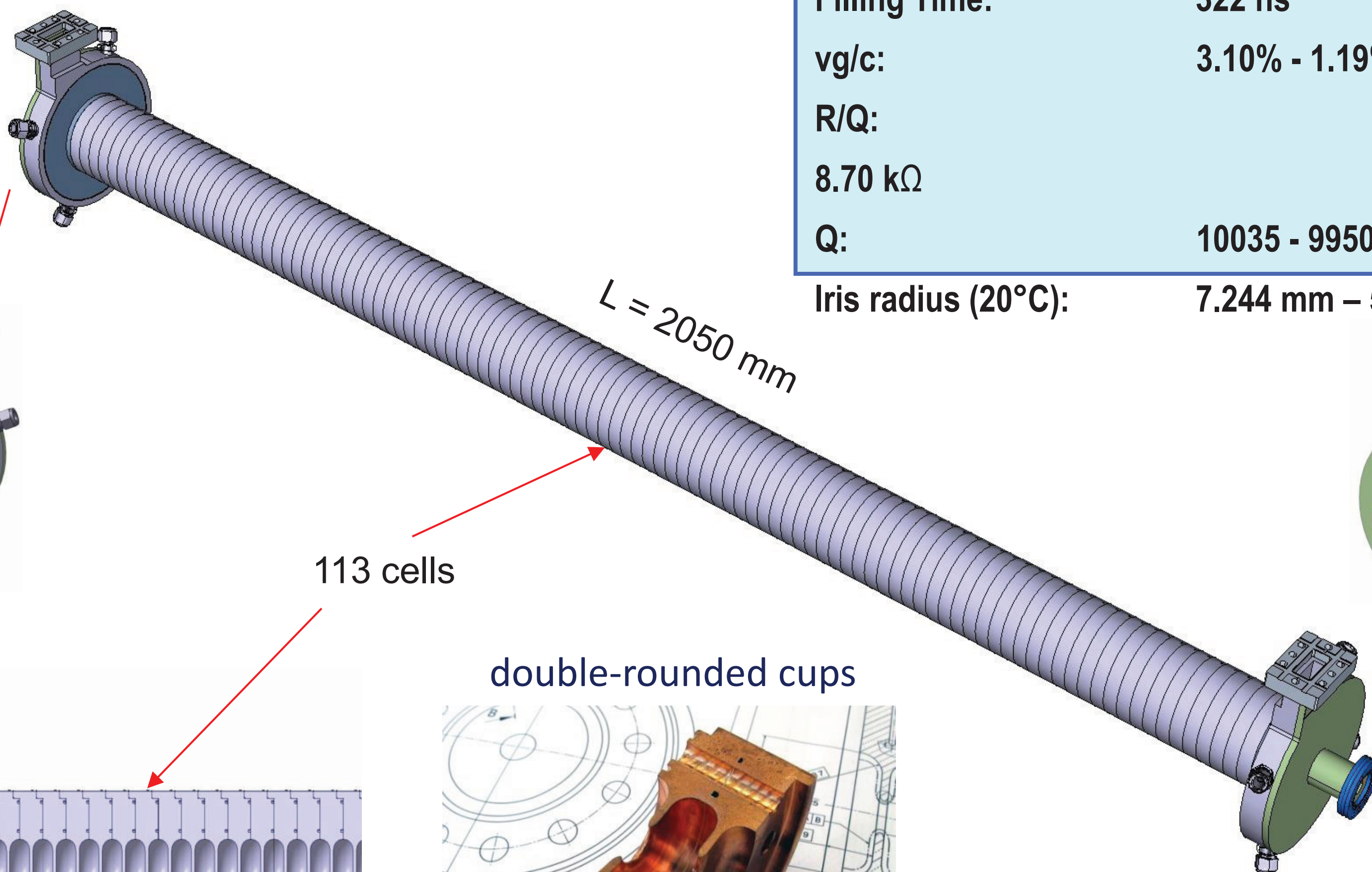
50MW Klystron and K2-3 Modulator

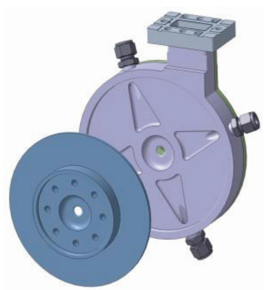
Based on K2-series: new control system, new mechanical layout.
Achieves excellent pulse shape and an rms stability of 13 ppm.

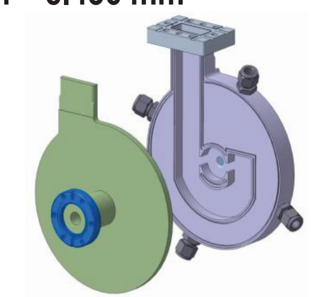
C-band structure

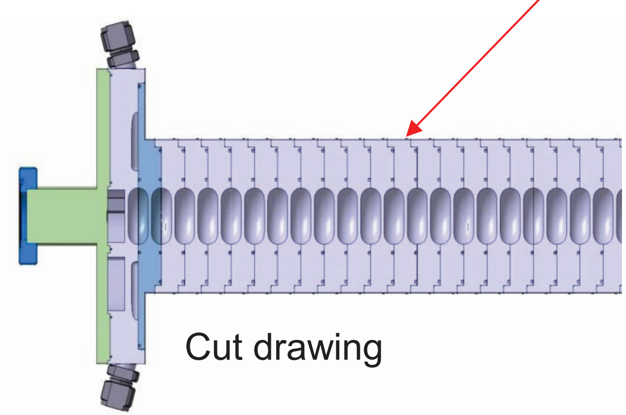
Structures are built without a tuning step

Specifications:	
Phase adv.	2π/3
Filling Time:	322 ns
vg/c:	3.10% - 1.19%
R/Q:	7.23 kΩ – 8.70 kΩ
Q:	10035 - 9950
Iris radius (20°C):	7.244 mm – 5.436 mm

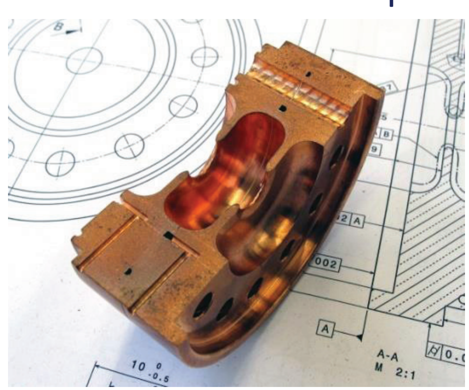








double-rounded cups



Stacking of C-band structure

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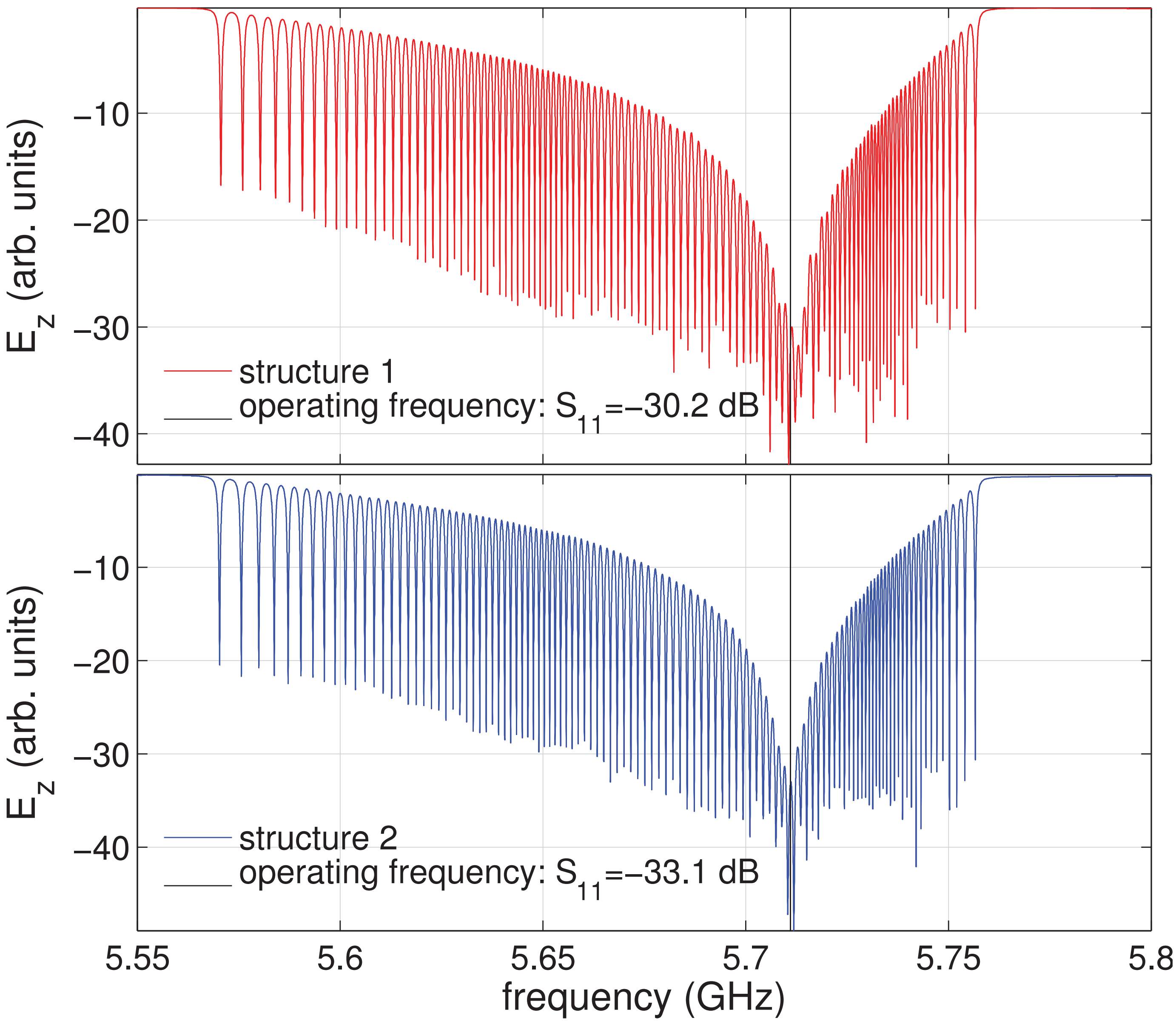
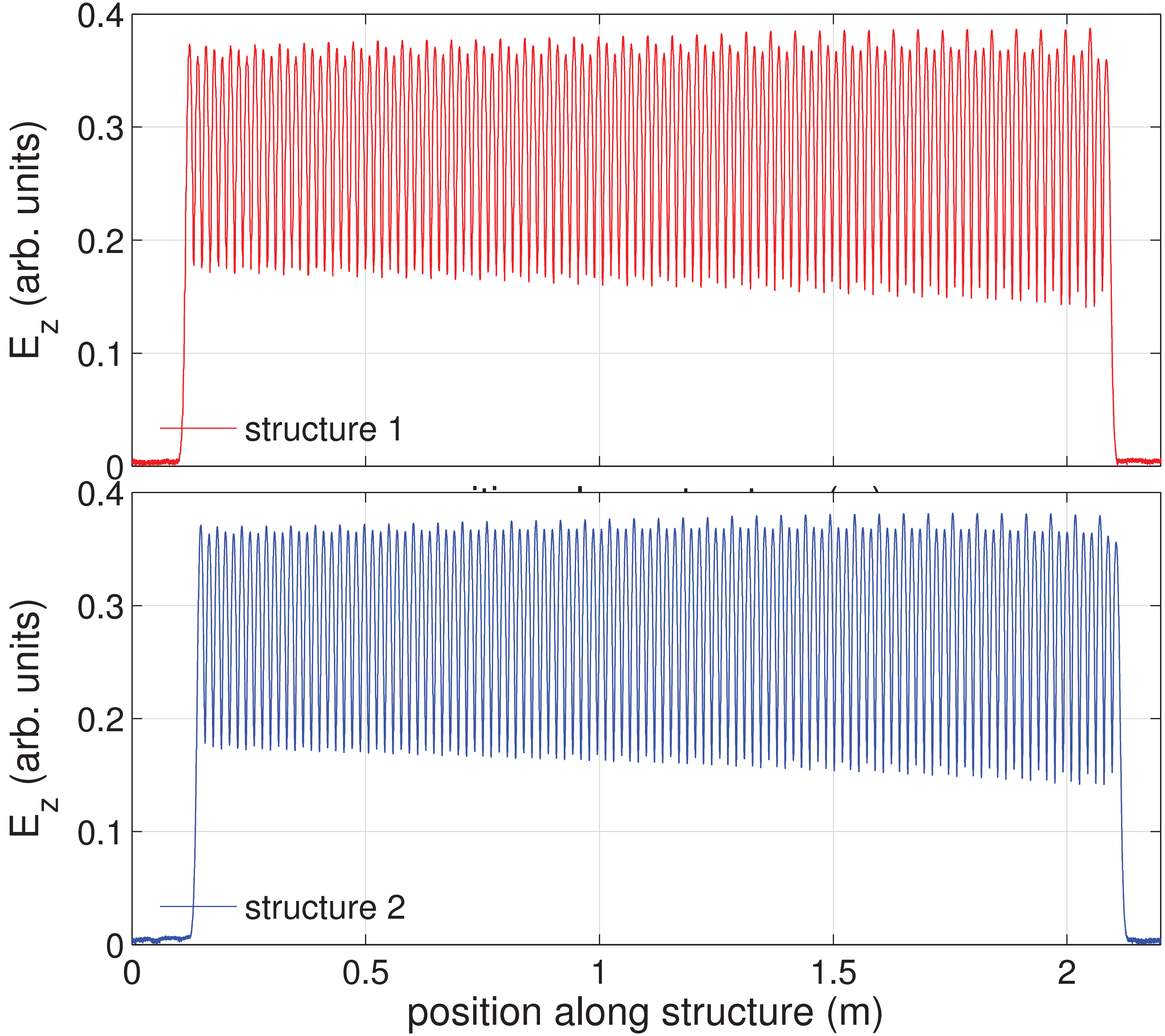
First 2 m C-band structures

- **5 structures have been brazed**
  - → First two structures were not vacuum tight after the brazing but they could be repaired with a second brazing step.
  - → Brazing procedure changed for third structure. Structure 3 & 4 are vacuum tight after the brazing. Structure 5 had again a vacuum leak (repaired).
- **Structures have been characterized with a bead pull measurements**
- **High power results for first structure:**
  - → 52 MV / m (~28 MW from klystron), limit was radiation shielding
  - → Break-down rate at 52 MV / m is ~2.1 x 10^{-6}
  - → At the nominal gradient, this gives excellent break-down rate

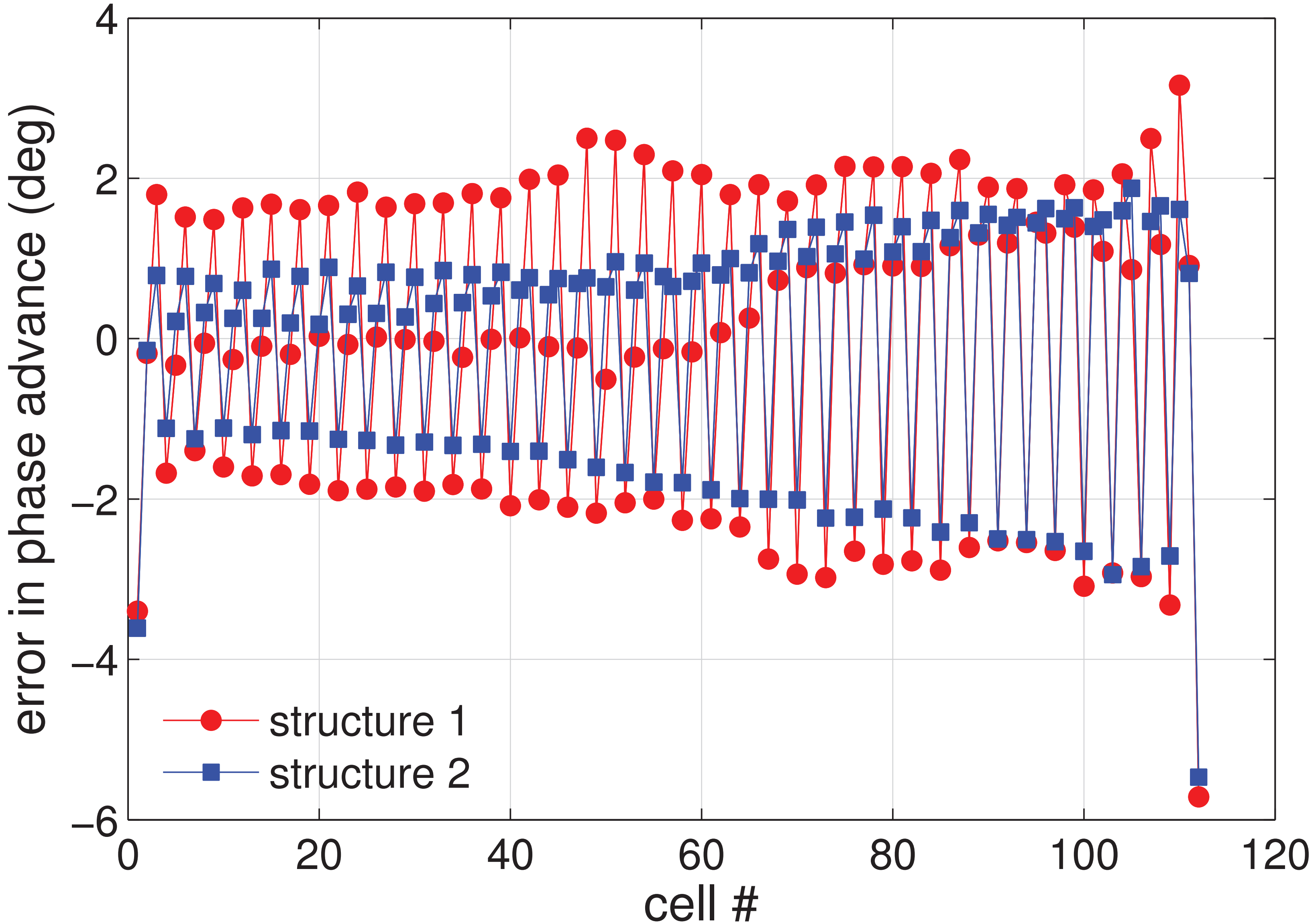
2 m C-band structure: reflection parameter



2 m C-band structure: longitudinal field distribution



2 m C-band structure: phase advance errors



Strategy for series production

C-band structures:

- Main partner for production of cups: **TEL Mechatronics**
- Additional cups produced by **VDL**
- J-couplers produced by **VDL**
- Brazing of J-couplers and stacking / brazing of structures at PSI

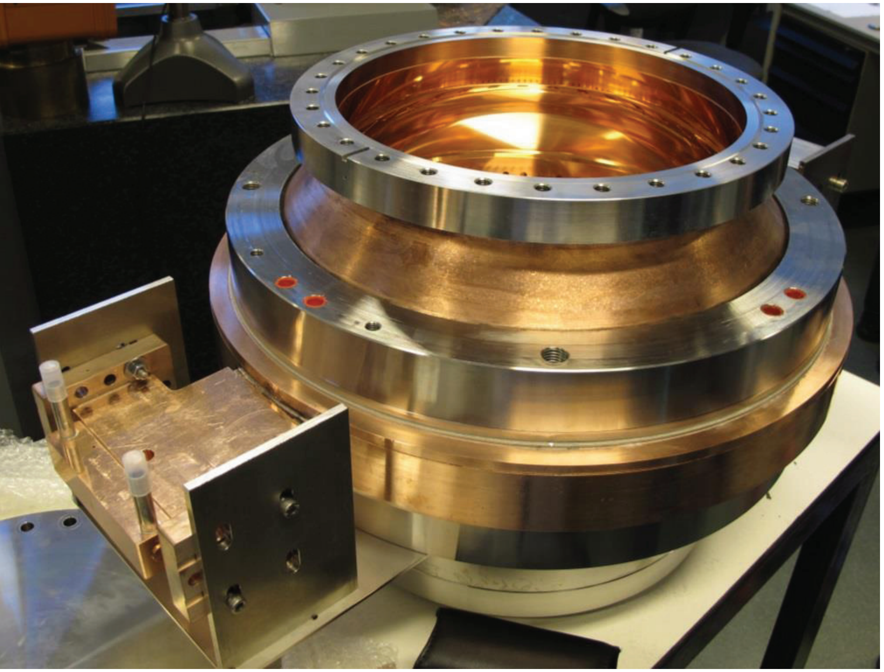
BOC pulse compressors:

- Production at PSI

Waveguides / loads

- **MHI** will produce the waveguide network
- **CML** will produce the water loads

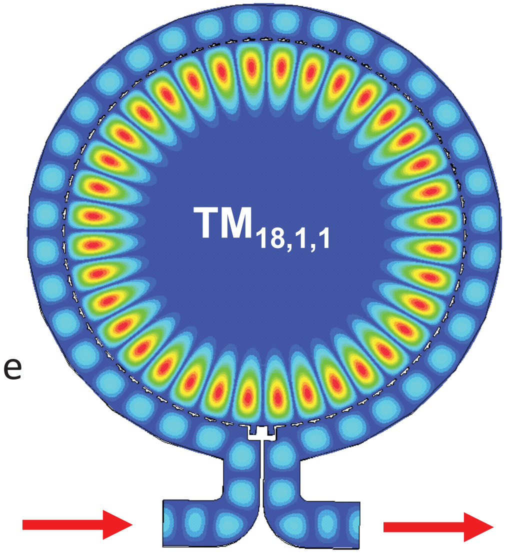
Pulse compressor
Whispering gallery mode: intrinsically high Q

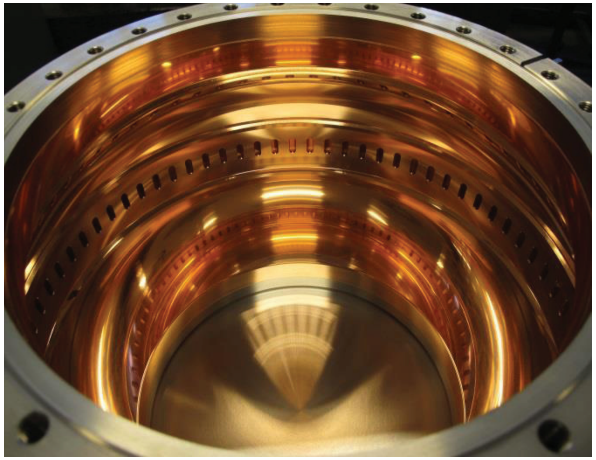


RF design:

Very simple design:

- ✓ Single cavity
- ✓ Whispering gallery mode with analytical solution
- ✓ intrinsic high Q





Mechanical design:

Very simple and robust design:

- ✓ Inner body from a single piece
- ✓ Two brazing steps

R. Zennaro

BOC production at PSI

#	Maker	Tuning steps	f (MHz)	Q_0	Power test	Breakdown rate [1])
0	VDL	4	5711.952	219000±4000	✓	$3 \cdot 10^{-8}$ (35 MW; phase jump) (1) $2*10^{-8}$ (40 MW phase modulation) (1)
1	PSI	4	5712.061	226000±4000	✓	$1*10^{-7}$ (40 MW phase jump) (2)
2	PSI	3	5711.944	225000±4000	-	-
3	PSI	2	5712.159	218000±4000	-	-
4	PSI	0	5711.979	217000±4000	Next test	
5-8	PSI	0	Under production			
9-30	PSI	0	Series production			

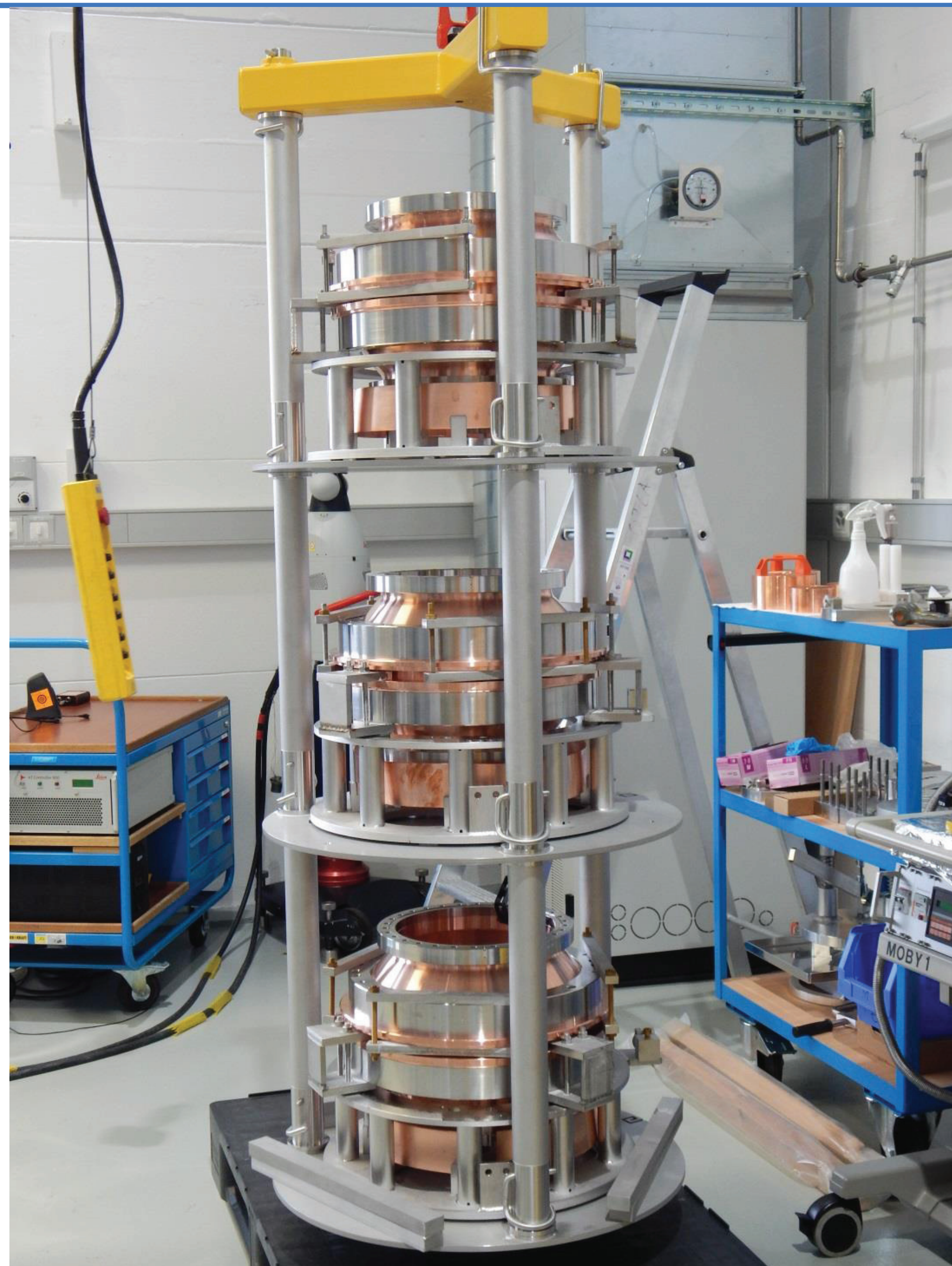
No tuning

1) Very likely the BDR was limited by a waveguide bend placed at the BOC output. Post test inspection shows no clear BD indication on the BOC surface, instead we had a large amount of BD spots on the bend surface. BDR with phase jump at 40 MW was only $5x10^{-7}$.

2) PSI BOC 1 conditioned much faster.This BDR result has been obtained only after removal of the waveguide bend which was limiting the performance before.

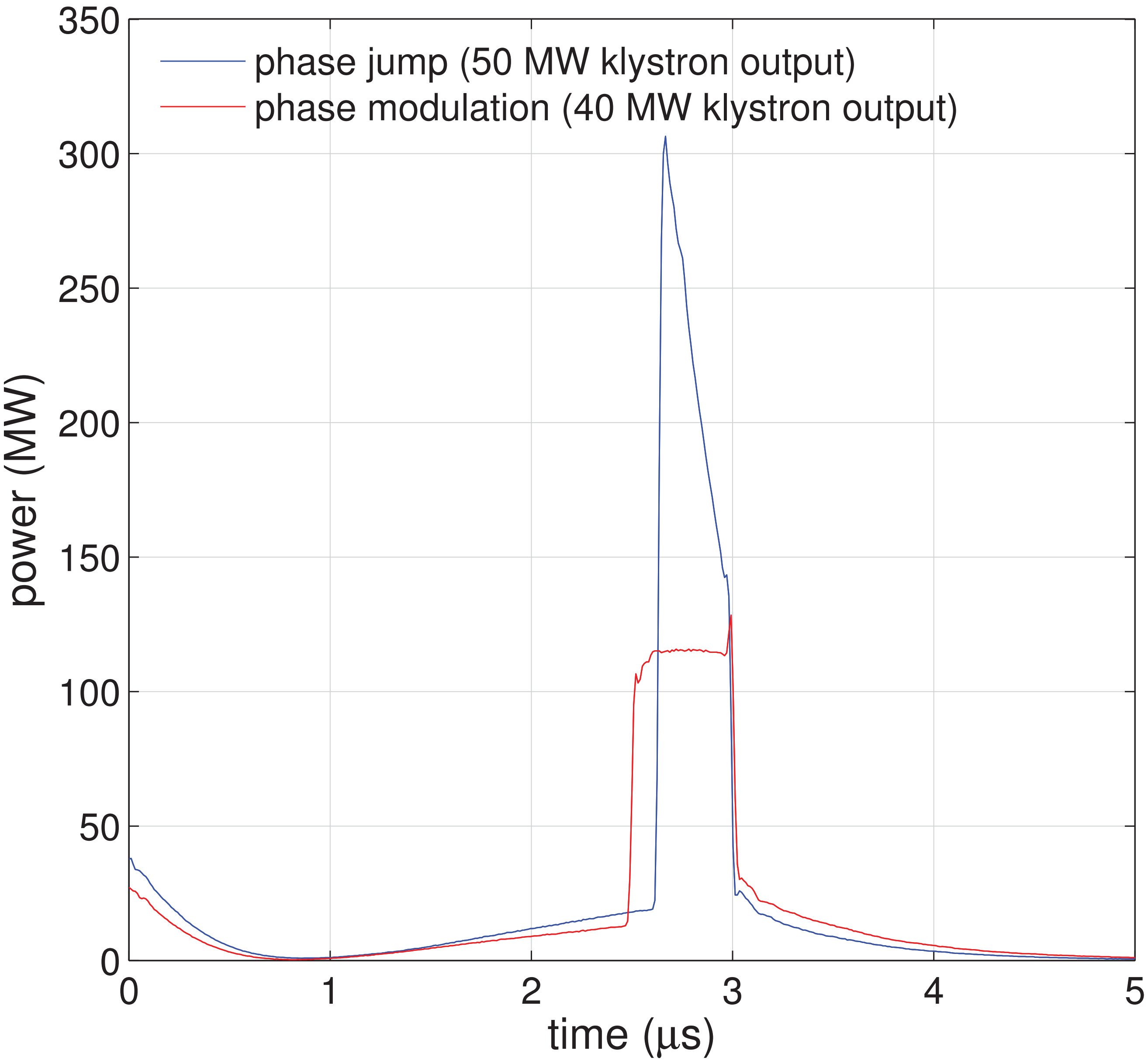
R. Zennaro

Simultaneous brazing of 3 BOCs



For more information see **THP056**

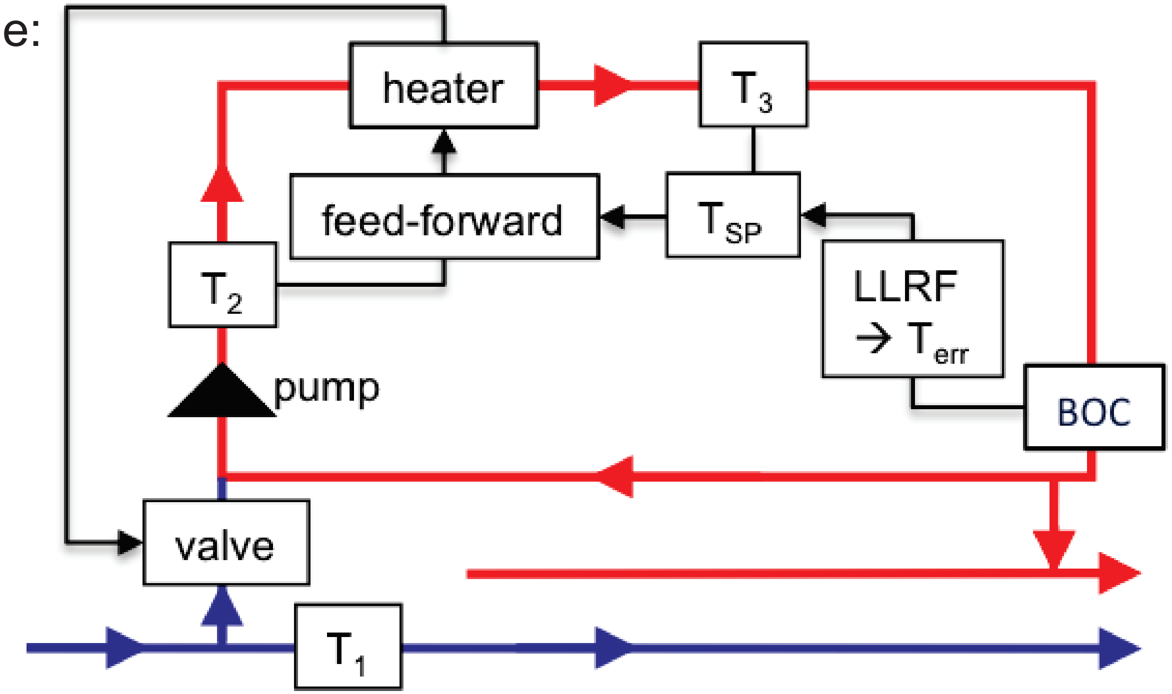
High power results from first BOC prototype (40 / 50 MW, 3 μs pulse from klystron)



R. Zennaro

Principle of the temperature regulation units

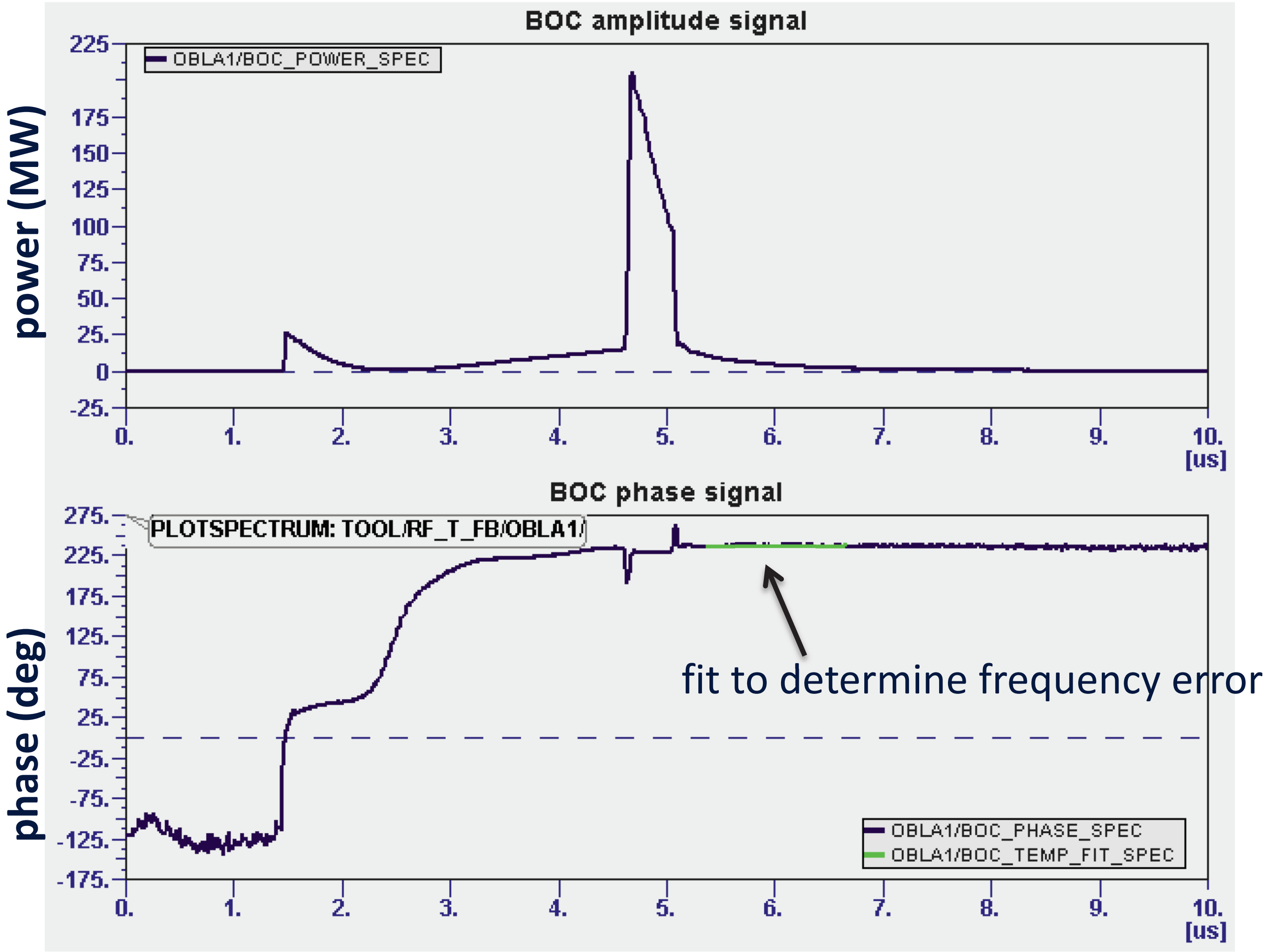
Principle:



Prototype system was commissioned in spring 2013

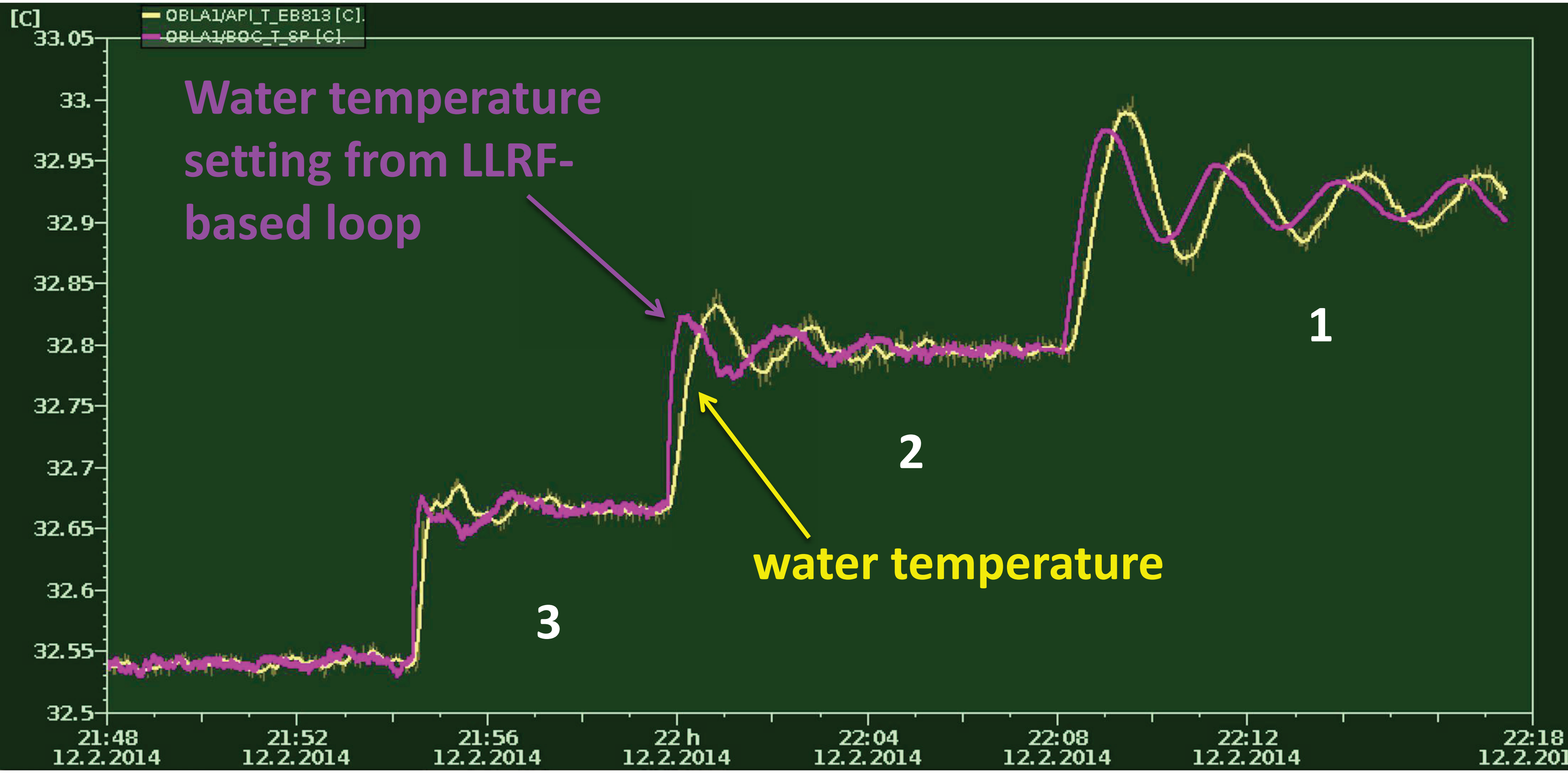
- Mixing ratio of ~ 1:10 improves temperature stability in stabilized circuit by factor of 10 compared to supply water
- A linearly regulated heater is used in a regulation loop to improve the stability further
- Temperature sensors are used as monitors when RF is turned off
- LLRF-based temperature measurement is used as an additional monitor during RF operation

BOC temperature stabilization



Temperature stability (T-sensor based):	~3 mK rms
BOC frequency stability (LLRF based):	~300 Hz
BOC temperature stability (LLRF based):	~3 mK rms

BOC temperature stabilization



Lowering response time when BOC temperature is changed:

1. LLRF-based loop with integrator only
2. LLRF-based loop with integrator & proportional control
3. Additional cubic term in feed-forward loop

Storage and assembly area for C-band modules

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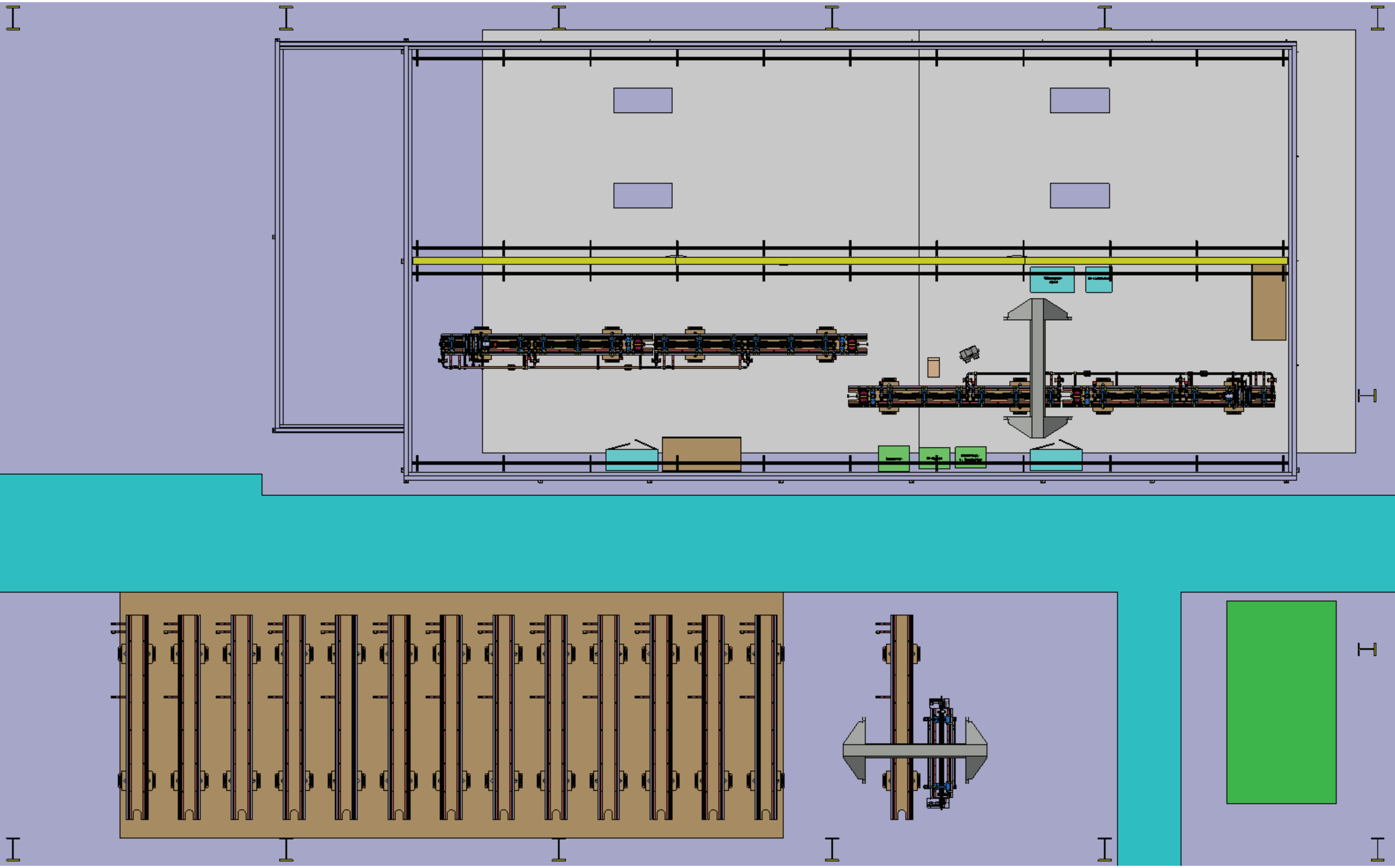
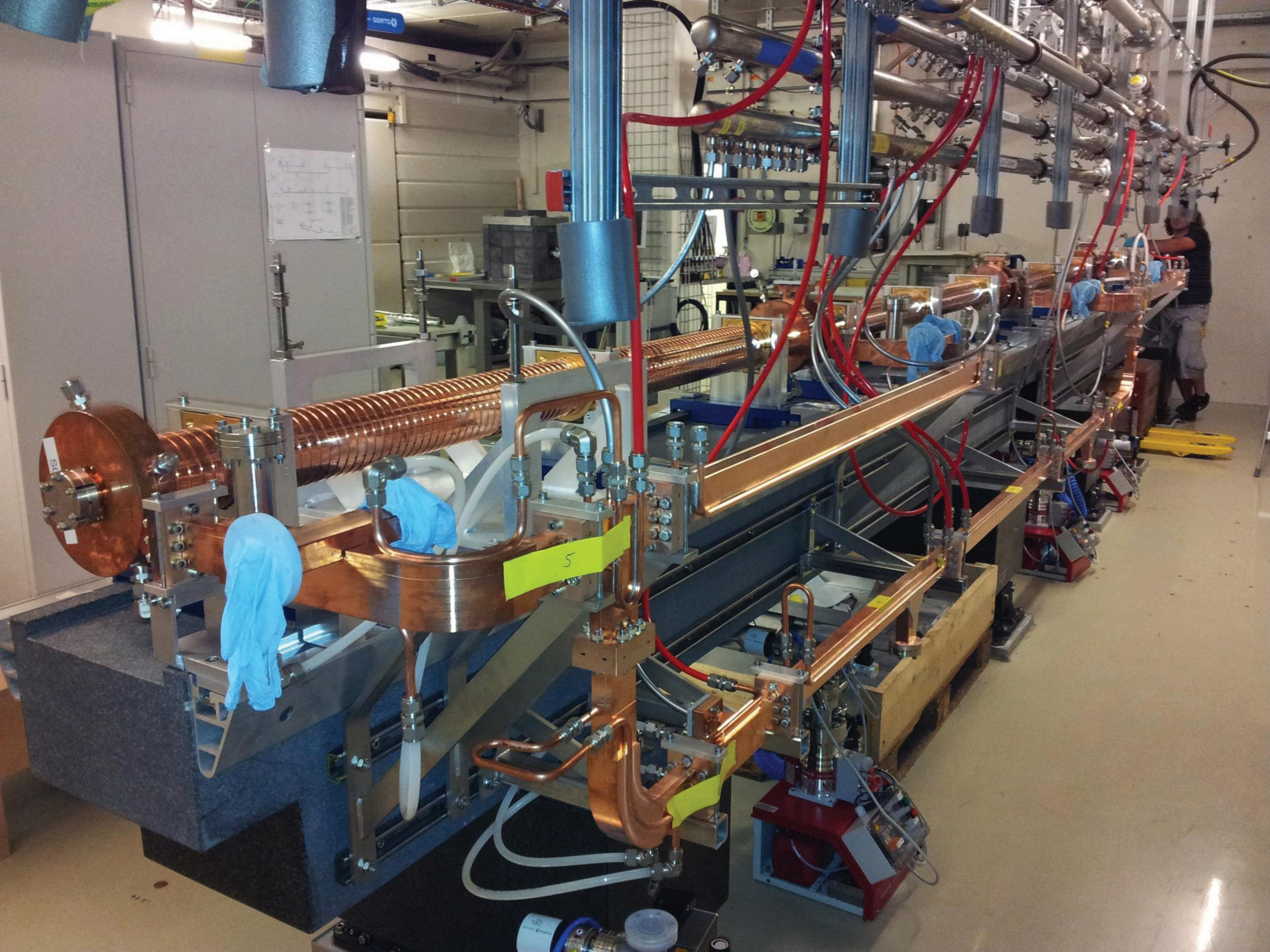


C-band module assembly area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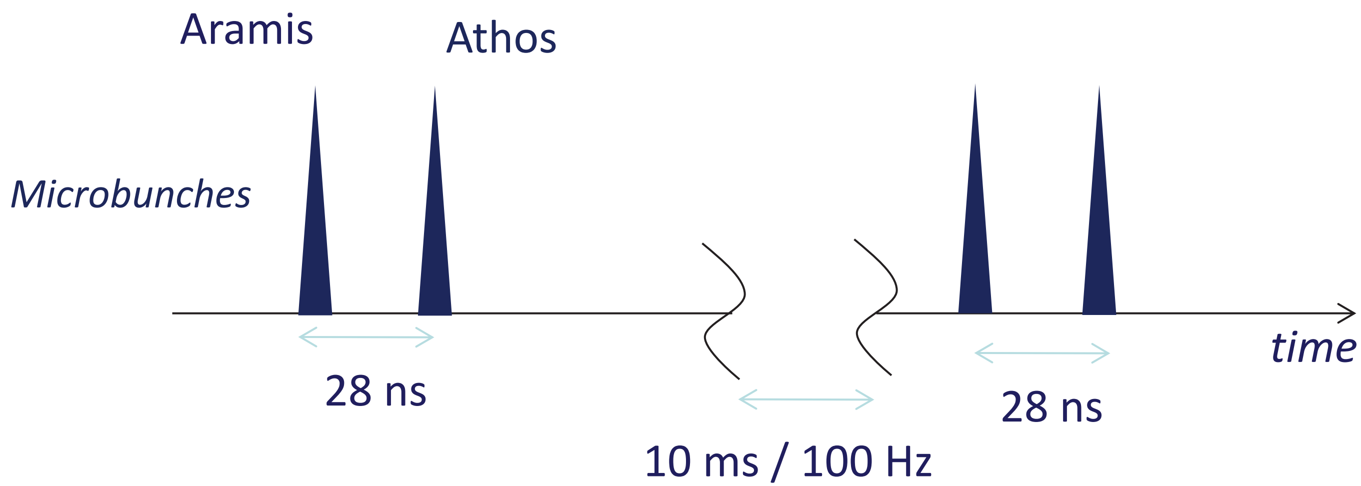
Thank you!
19.8.2014

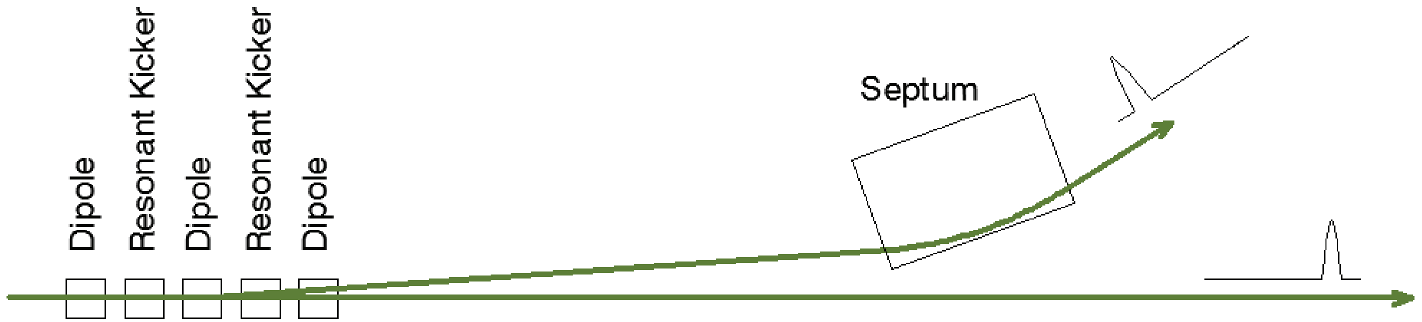
Simultaneous operation of Aramis and Athos

Time structure:



Switch-yard:

Will allow simultaneous operation of Aramis and Athos at 100 repetition rate



Switch-yard: Fast resonant kicker development

Kicker system

Number of kickers	2
Kickers type	In vacuum
Bunch separation	28 ns
Total deflection angle	1 mrad (vertical)
Deflection stability	±80 ppm pk-pk
Total magnetic length	1.5 m
Line field integral	10 mT.m
Deflecting current	500 A pk-pk

Septum

Number of septums	1
Septum type	Lambertson, DC
Total deflection angle	2° (horizontal)
Deflection stability	±10 ppm pk-pk
Total magnetic length	1.0 m
Line field integral	350 mT.m

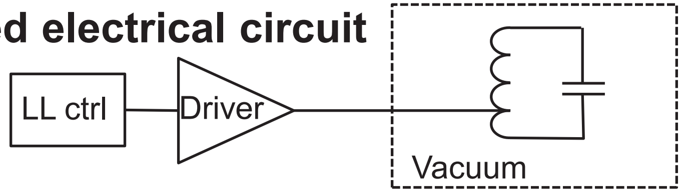
For more information check the poster contribution **MOP039: M. Paraliev at al.**

*"**High Stability Resonant Kicker Development for the SwissFEL Switch Yard**"*

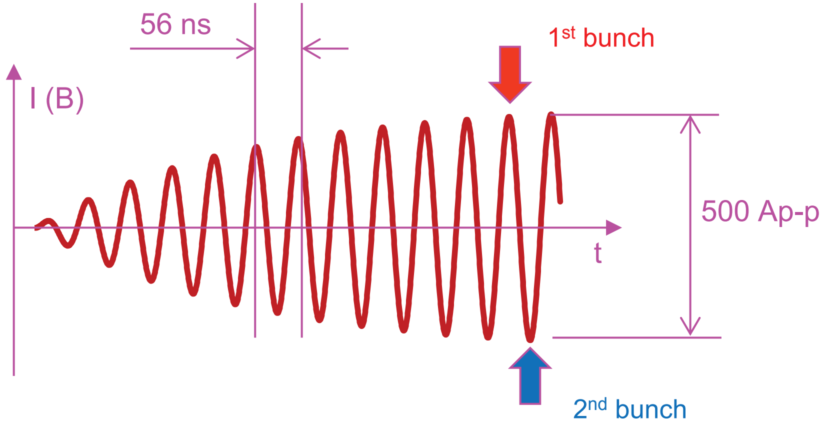
(the poster was presented yesterday)

Prototype kicker resonator

Simplified electrical circuit



Deflecting current build-up



Achieved kicker (prototype) stability: < ±15 ppm pk-pk