

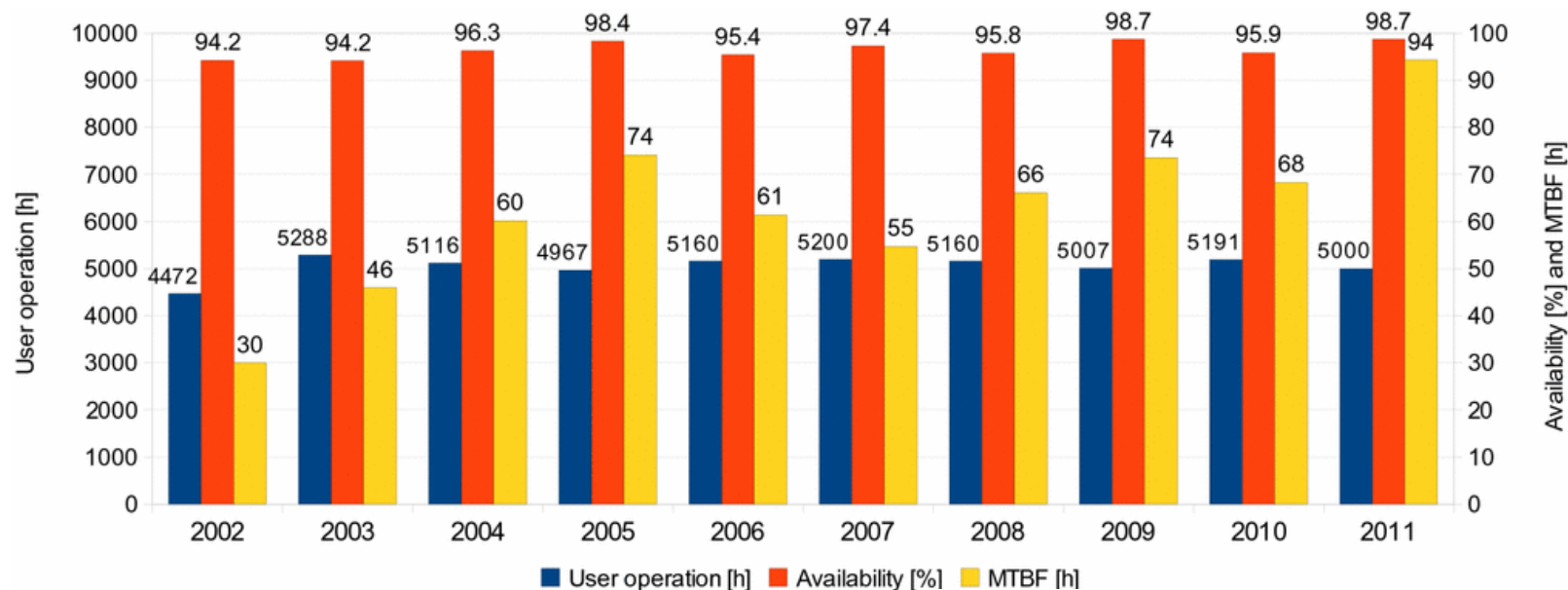


Wir schaffen Wissen – heute für morgen

Paul Scherrer Institut
Lukas Stingelin for the PSI rf-group
RF Operation and Developments at PSI

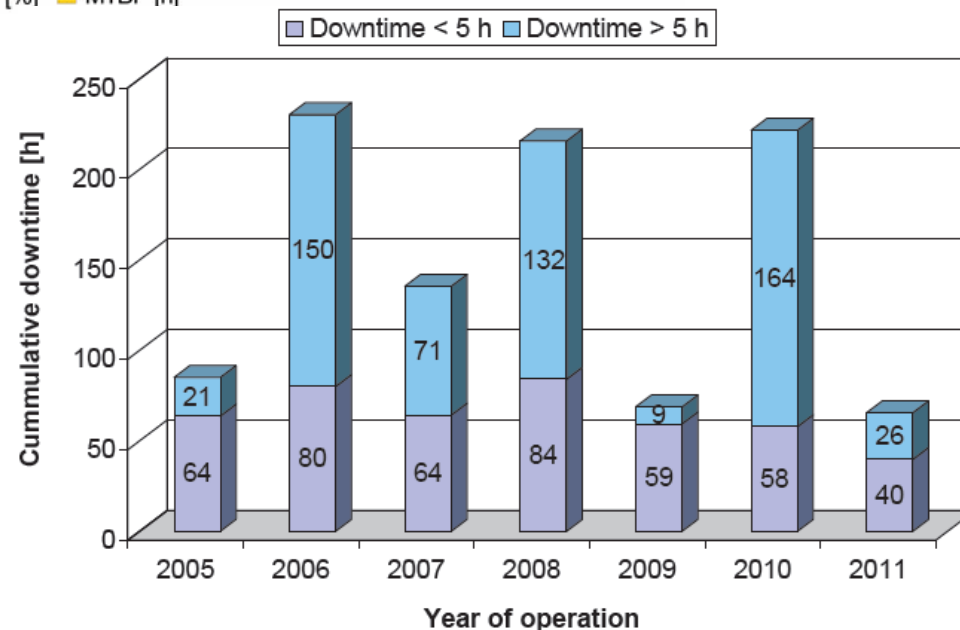
- **Operation Statistics**
- **LINAC Problems and Upgrades**
- **500MHz Klystron Problems**
- **Problems with Instabilities**
- **Cavitation analysis of input power coupler**
- **Commissioning of RF-Systems for the SwissFEL**

Operation Statistics



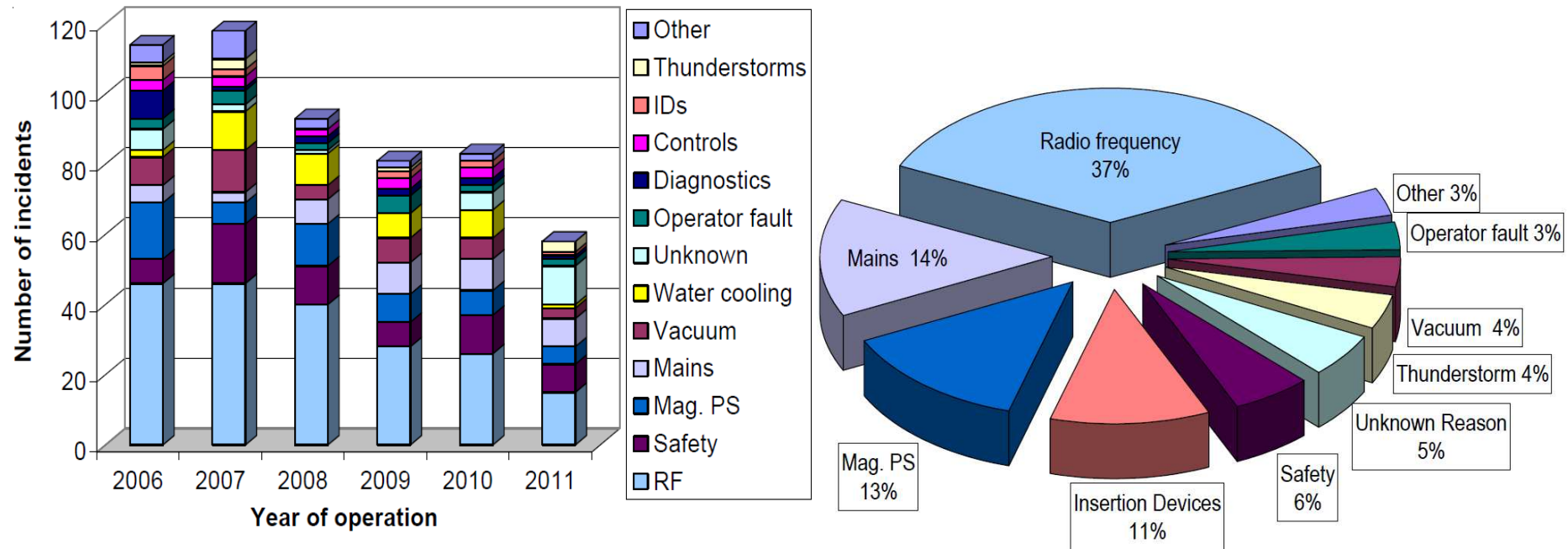
In 2011:

- 10 years of SLS user operation!
- New record for vertical beam emittance (1 pico-m-rad)
- Overall Mean Time Between Failures reached 94h (also thanks to new coincidence arc detectors)



A.Lüdeke et al., PSI annual report 2011

Beam Outages per Failure Category in 2011



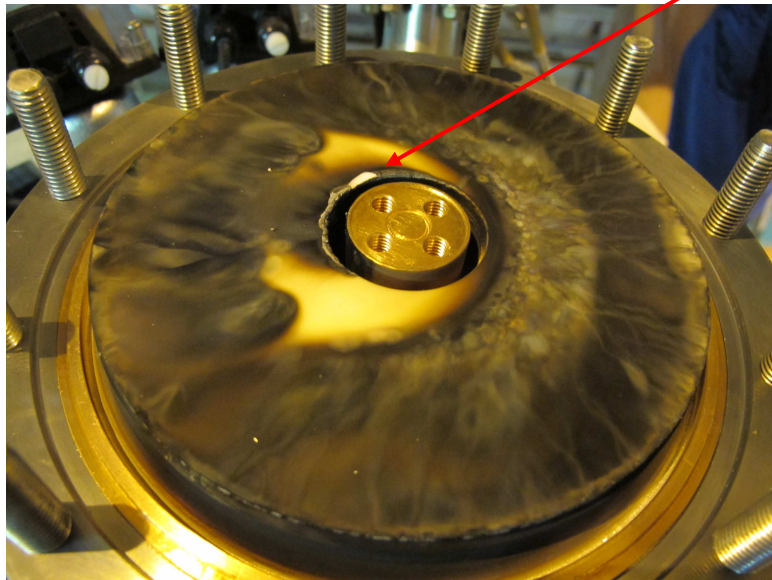
Major events in 2011:

- 2x trip of S3HC Helium compressor due to transient failures of power-supply (7.5 hours of user operation + failure during shutdown)
- Water leak in a storage-ring klystron (11 hours of user-operation)

Major Failures in 2012

- From end of January to mid March: problems with Coupled Bunch Instabilities (Problems during accumulation, broken input power coupler and operation only at 350mA).
- Problems with temperature measurement system of S3HC (5h+3h).
- Water leak at booster klystron (4h)
- Water-leaks at storage-ring cavities (repaired during shutdowns)
- Contamination of heat-exchanger in cryoplant of S3HC (required warm-up and regeneration during October shutdown)

Ceramic of Input Power Coupler with cracked chamfer

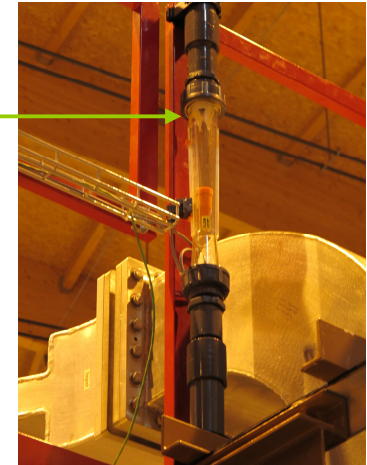


Dentist-tool to repair water-leaks:



Accomplished:

- ✓ New air flow-switch for klystrons installed
- ✓ Fire protection for LINAC modulators installed
- ✓ All storage-ring coincidence arc detectors installed
- ✓ Spare 500MHz RF cavities received from ELETTRA
- ✓ S3HC spare valve-box constructed at PSI workshop
- ✓ All Input Power Coupler replaced



Work in progress:

- ❑ 500MHz teststand at the booster rf plant (solidstate amplifier for booster cavity)
- ❑ Planned to replace one storage-ring cavity per year
- ❑ HOM detector boards from ELETTRA or PSI?
- ❑ Fire detectors for storage-ring klystron power supplies
- ❑ Refurbish Klystrons and optimize efficiency
- ❑ Spare solenoids for LINAC in construction (expected delivery in 2013)
- ❑ Repair of Klystron cooling circuits and support-frame (one Klystron per long shutdown)
- ❑ Replacement of anodized (badly conducting) coaxial-rings at IPC with rings plated with Alodyne

SLS-LINAC Problems and Upgrades



Tube for smoke detector 1

Fire extinguisher tube

Tube for smoke detector 2

- ✓ Installation of fire detectors and extinguisher at PFN-cabinet
- ✓ Improved water cooling distribution for the LINAC solenoids and wave guide components

- ❑ Problems with rubber hoses in „open“ cooling-circuit for the LINAC structures:



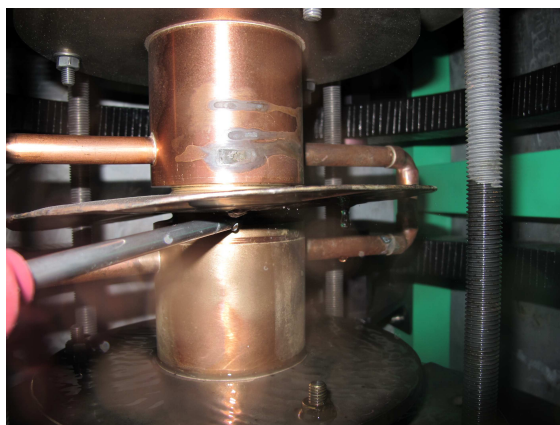
Problems with EEV 500MHz Klystron I



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

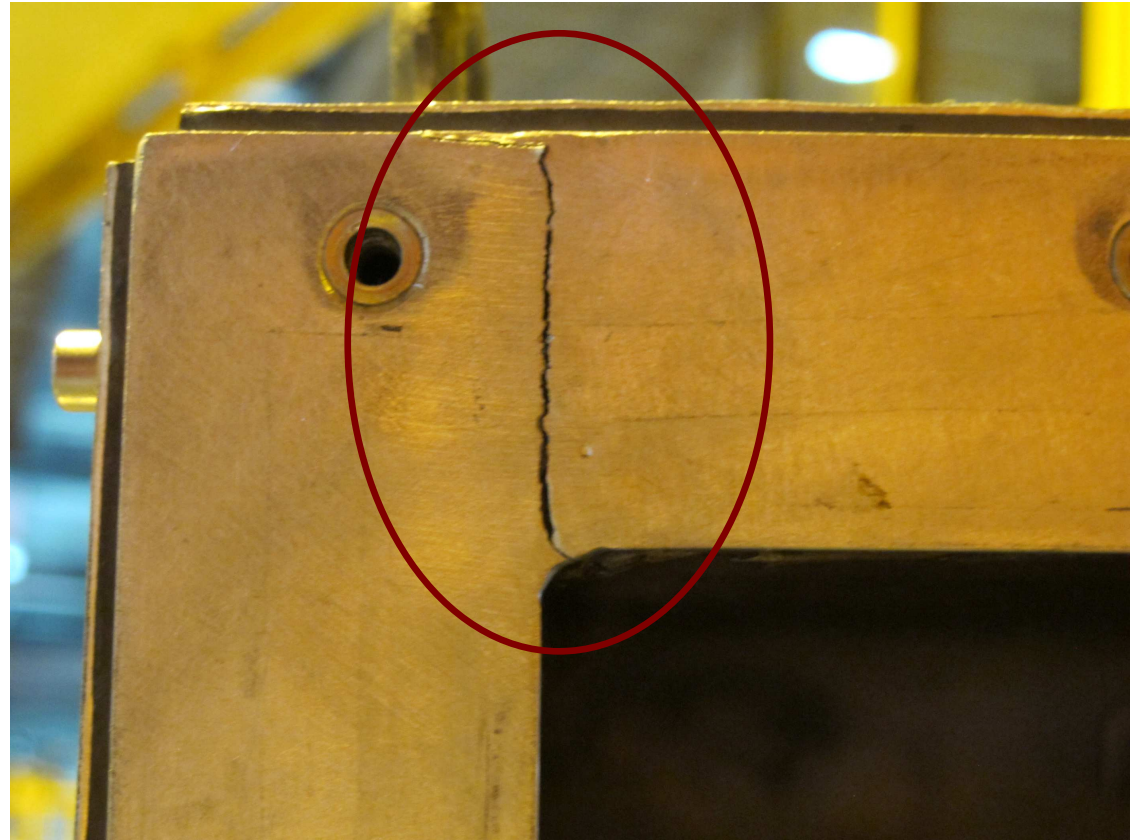


Problems with EEV 500MHz Klystron II

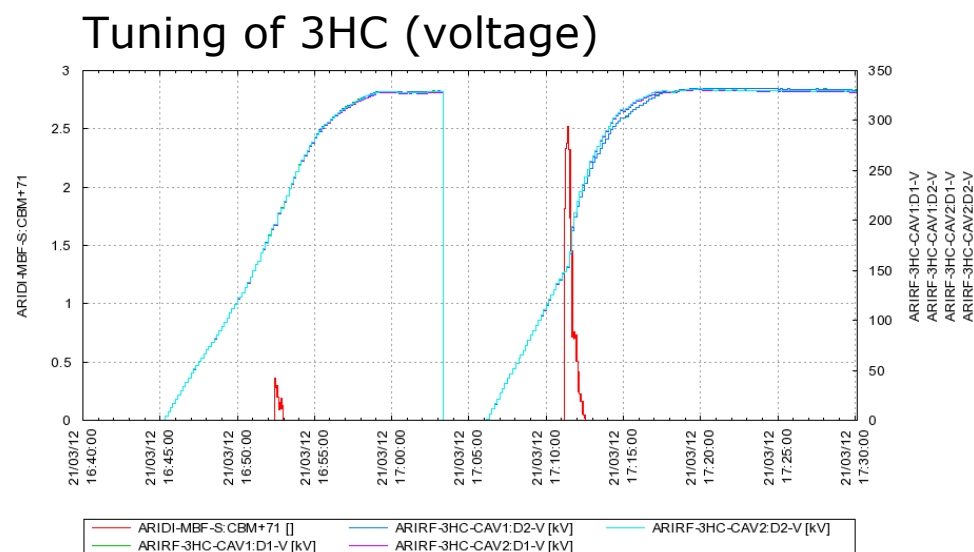
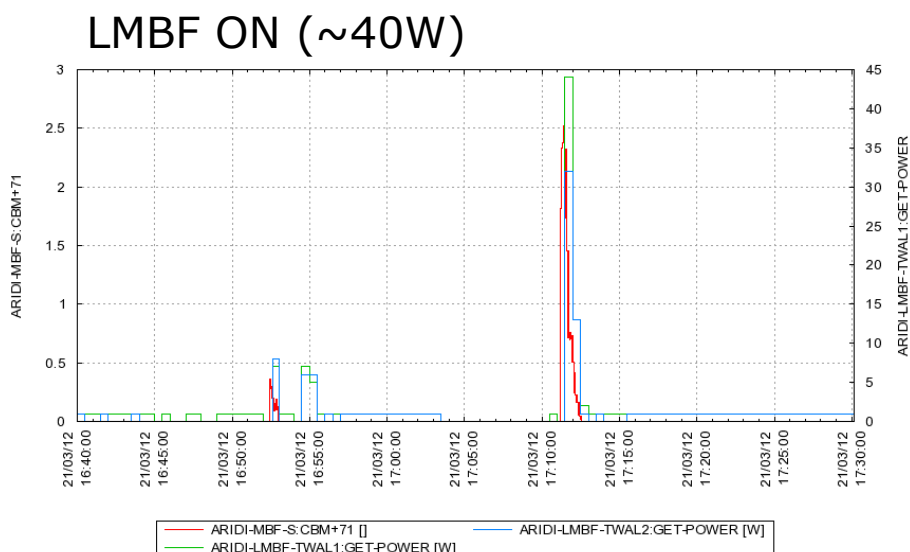
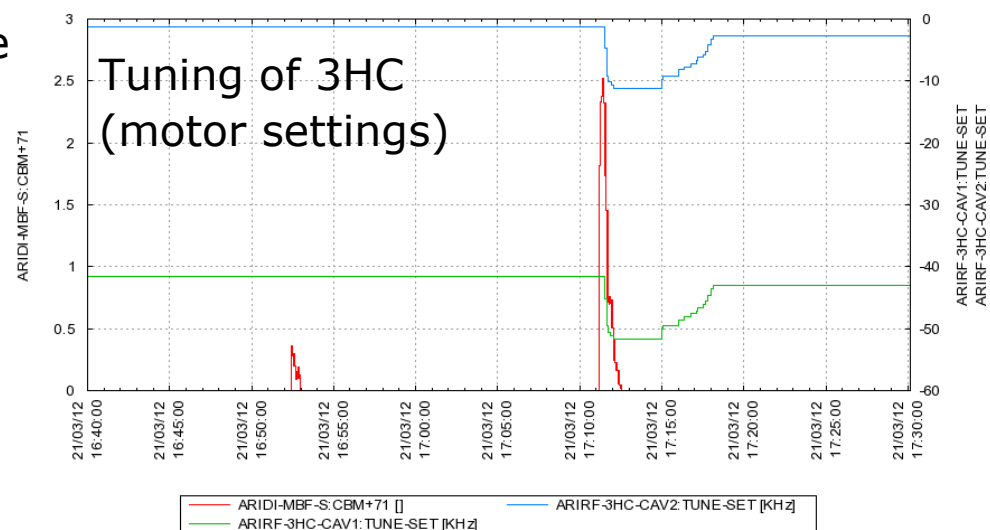
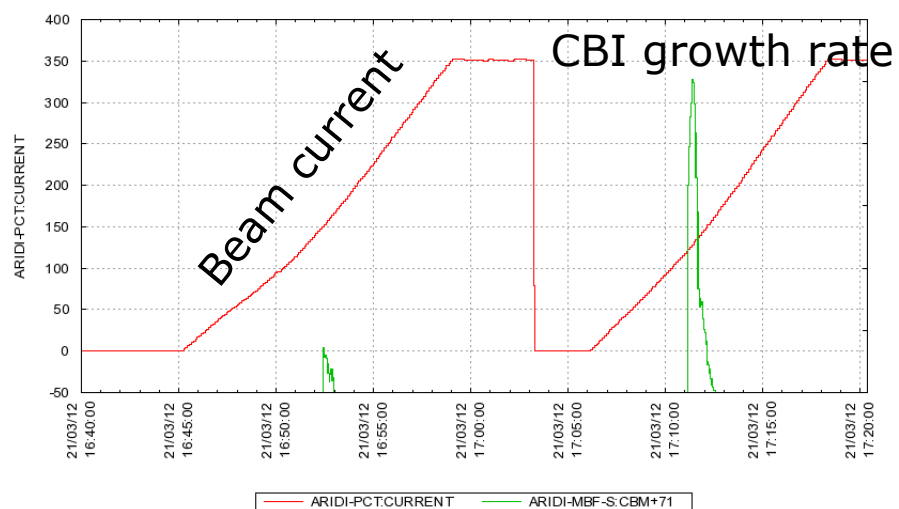


EEV Type K3418P Klystron

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



Issue with CBM +71



Courtesy of P. Craievich

Is CBM +71 a trapped mode between two cavities?

Mode	SLS C1	SLS C2	SLS C3	SLS C4
L1	430	430	430	431
L2	57	57	58	57
L3	405	406	407	405
L4	13	12	13	13
L5	104	105	106	104
L6	360	359	360	360
L7	430	429	430	430
L8	72	72	73	72
L8	72	72	74	73
L9	119	119		117

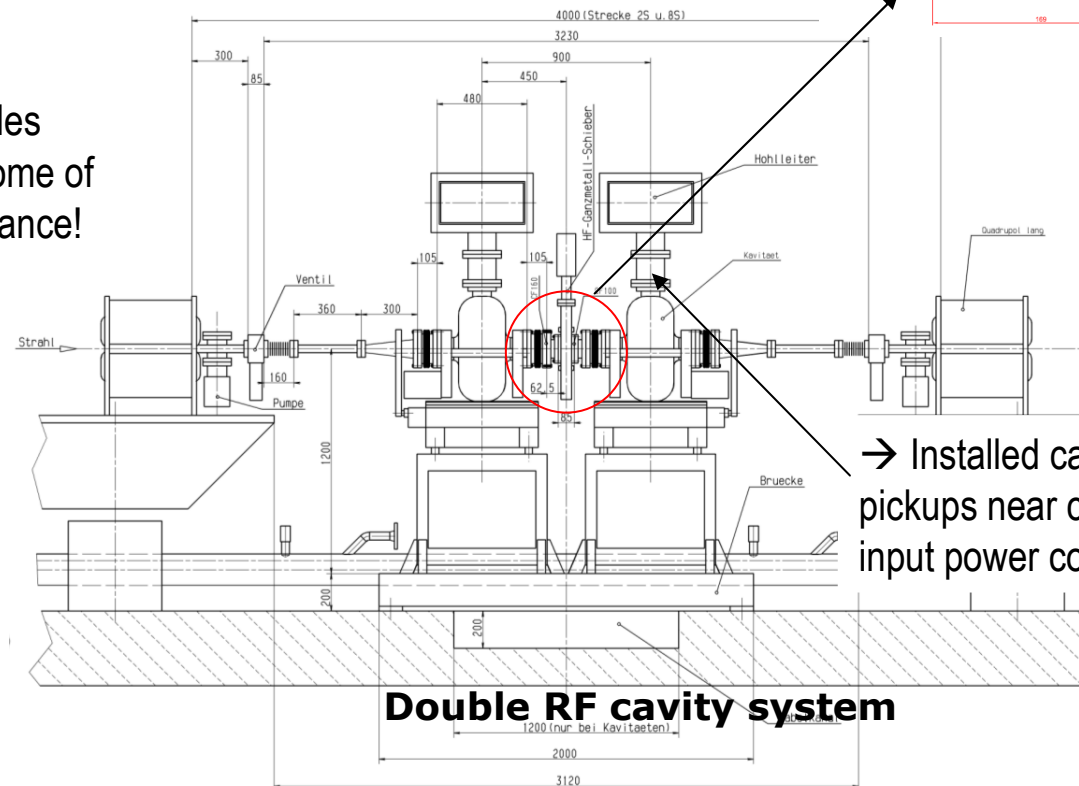
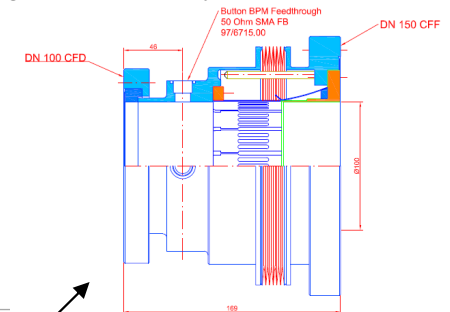
Impedance close to zero

There are many trapped resonances modes between two cavities and it seems that some of them could have an non-negligible impedance!

3HC longitudinal modes					
Mode	Freq [MHz]	R/Q [ohm]	Qmax	fr*R/Q*Q [GHz*kohm]	CBM
L1	2466	0.17	16000	6.7	449
L2	2532	2.60	1100	7.2	32
L3	2067	11.00	240	5.5	66
L4	2695	0.12	22000	7.1	189
L5	2826	6.57	380	7.1	315
L6	2979	8.61	270	6.9	462
L7	3084	1.93	1200	7.1	83
L8	3180	0.30	7500	7.2	175
L9	3358	0.86	2400	6.9	346
L10	3594	0.43	4500	7.0	93

Stability Limit for SLS: 73 GHz kohm @0.35A

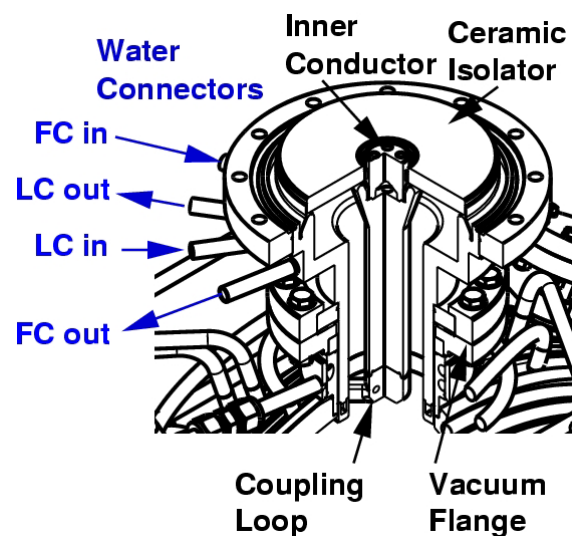
→ Install BPM bellows with SMS feedthrough
By L. Schultz



→ Installed capacitive pickups near ceramic of input power coupler.

Double RF cavity system

Acoustic Cavitation Analysis of Input Power Coupler



The experiment



Acceleration sensor



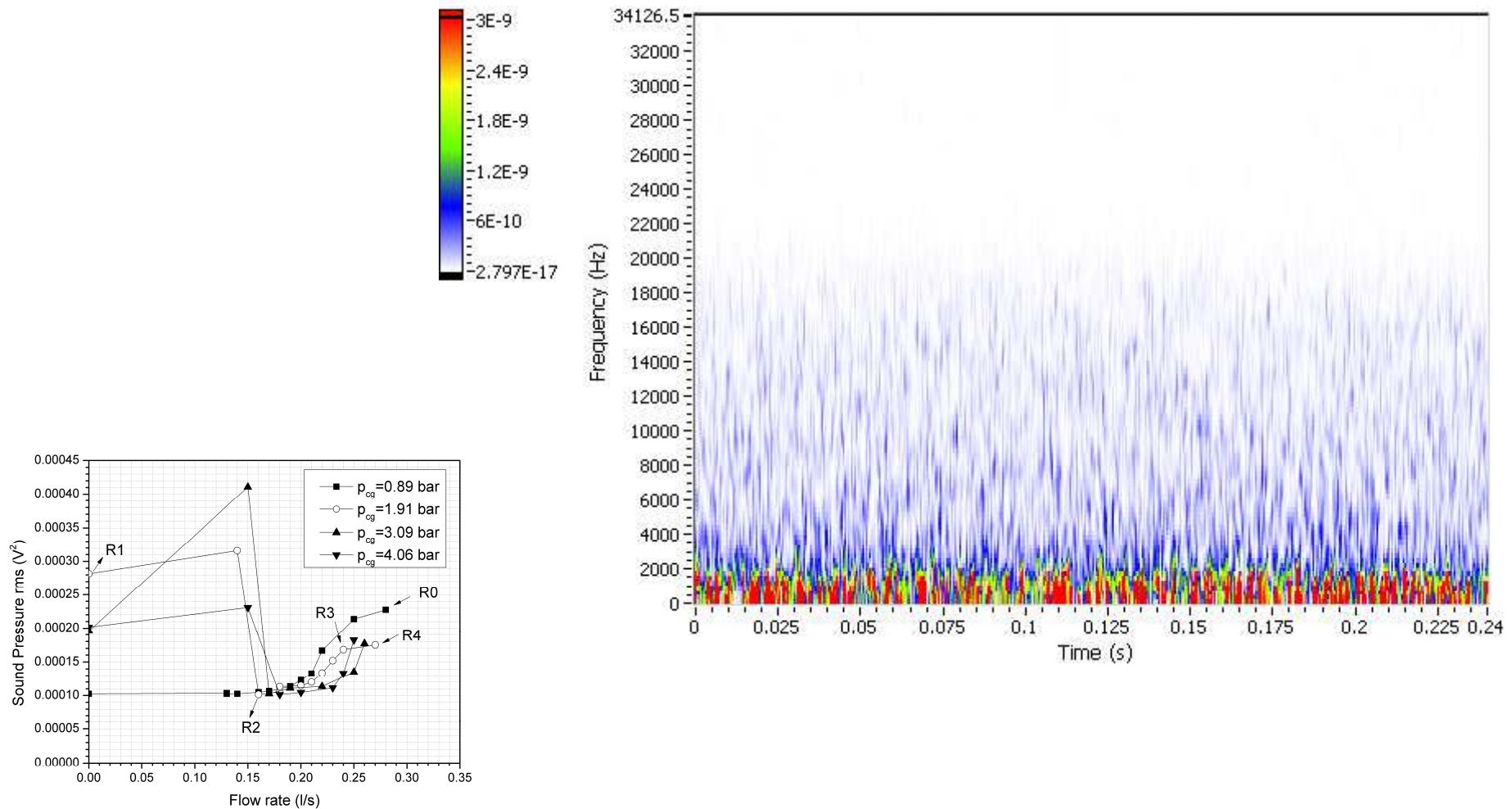
Acoustic emission sensor



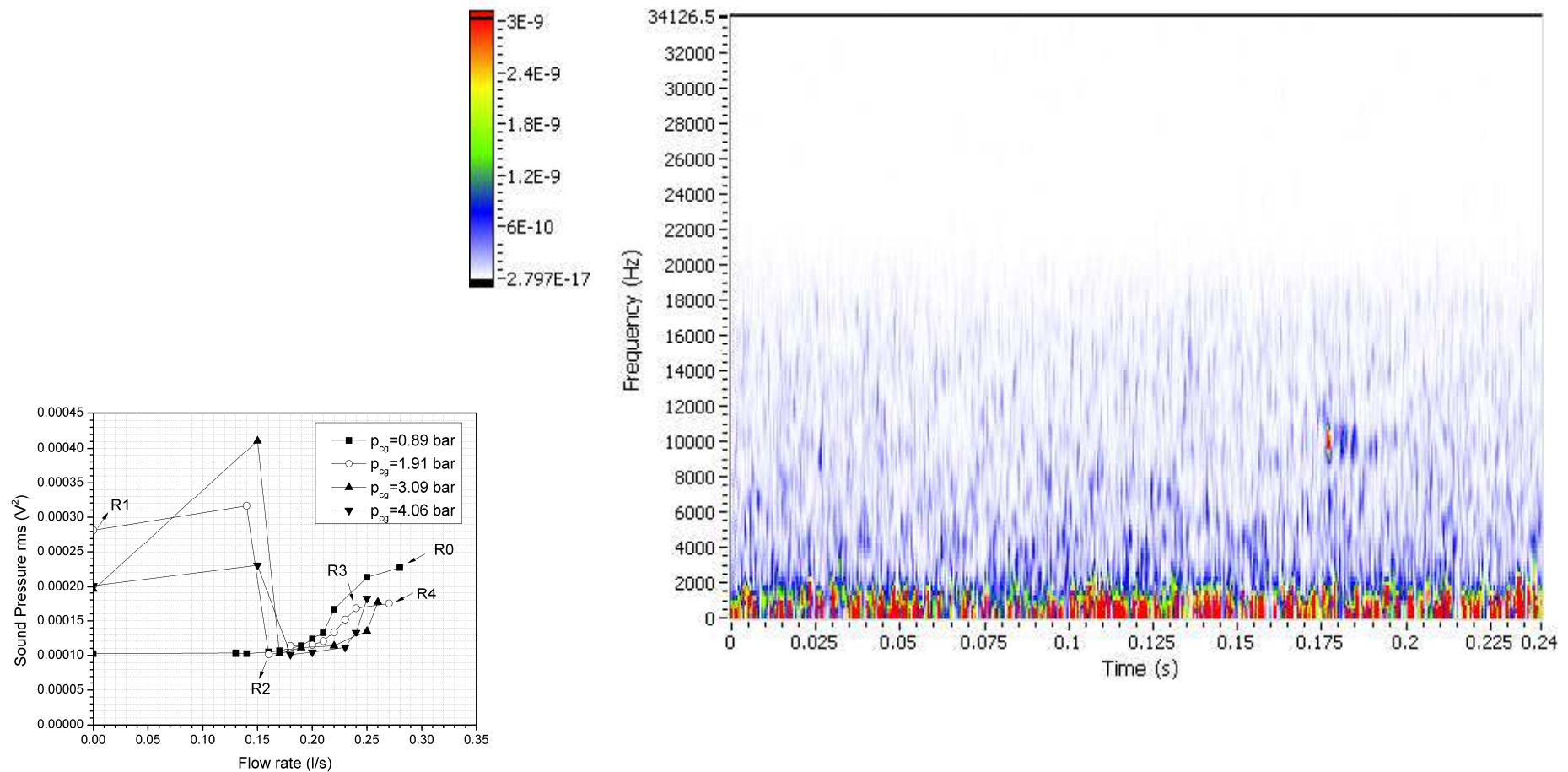
Microphone



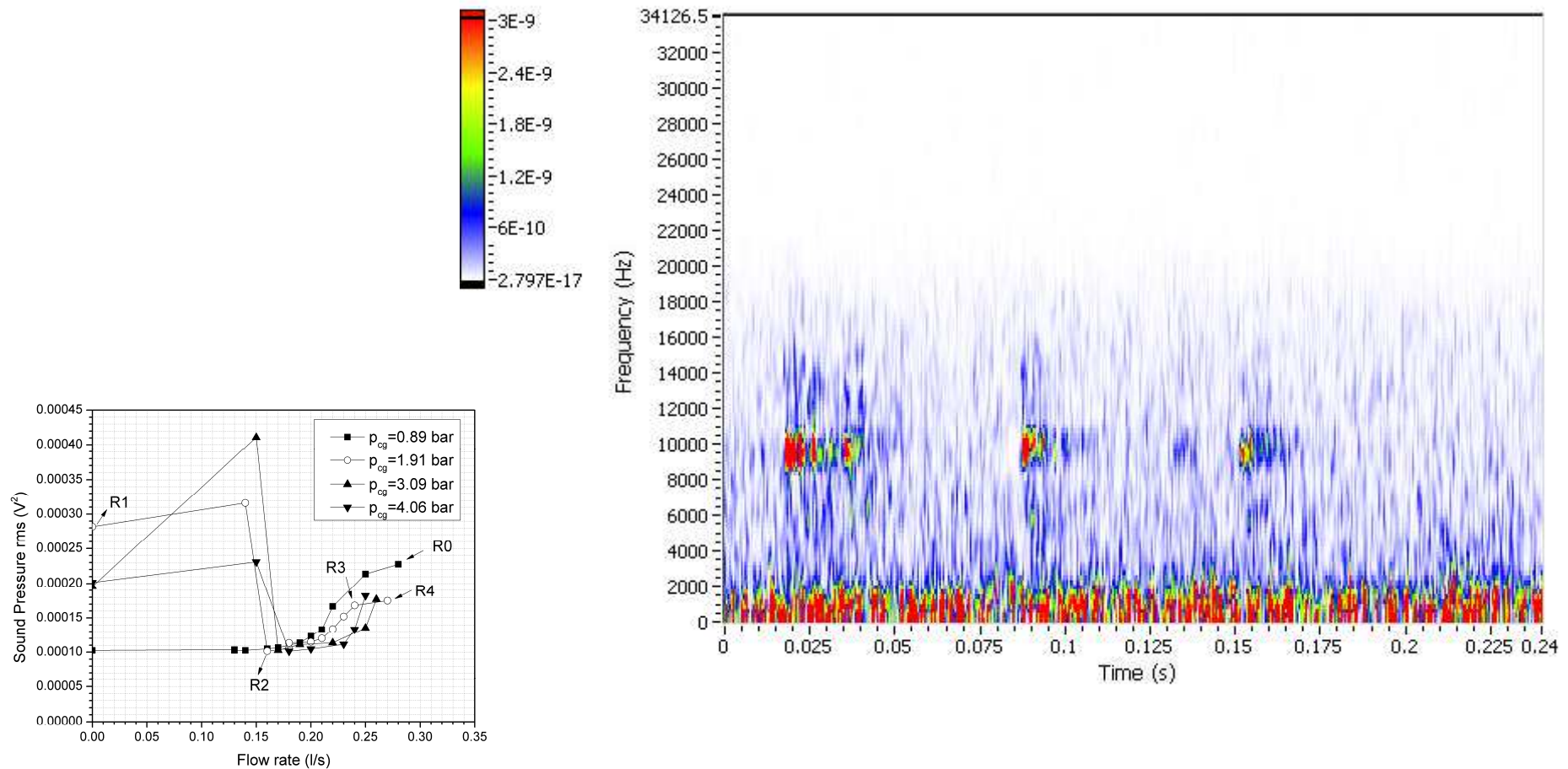
Regime 2 (1.91bar, 0.16l/s) → no cavitation



Regime 3 (1.91bar, 0.24l/s) → incipient cavitation



Regime 4 (1.91bar, 0.27l/s) → cavitation



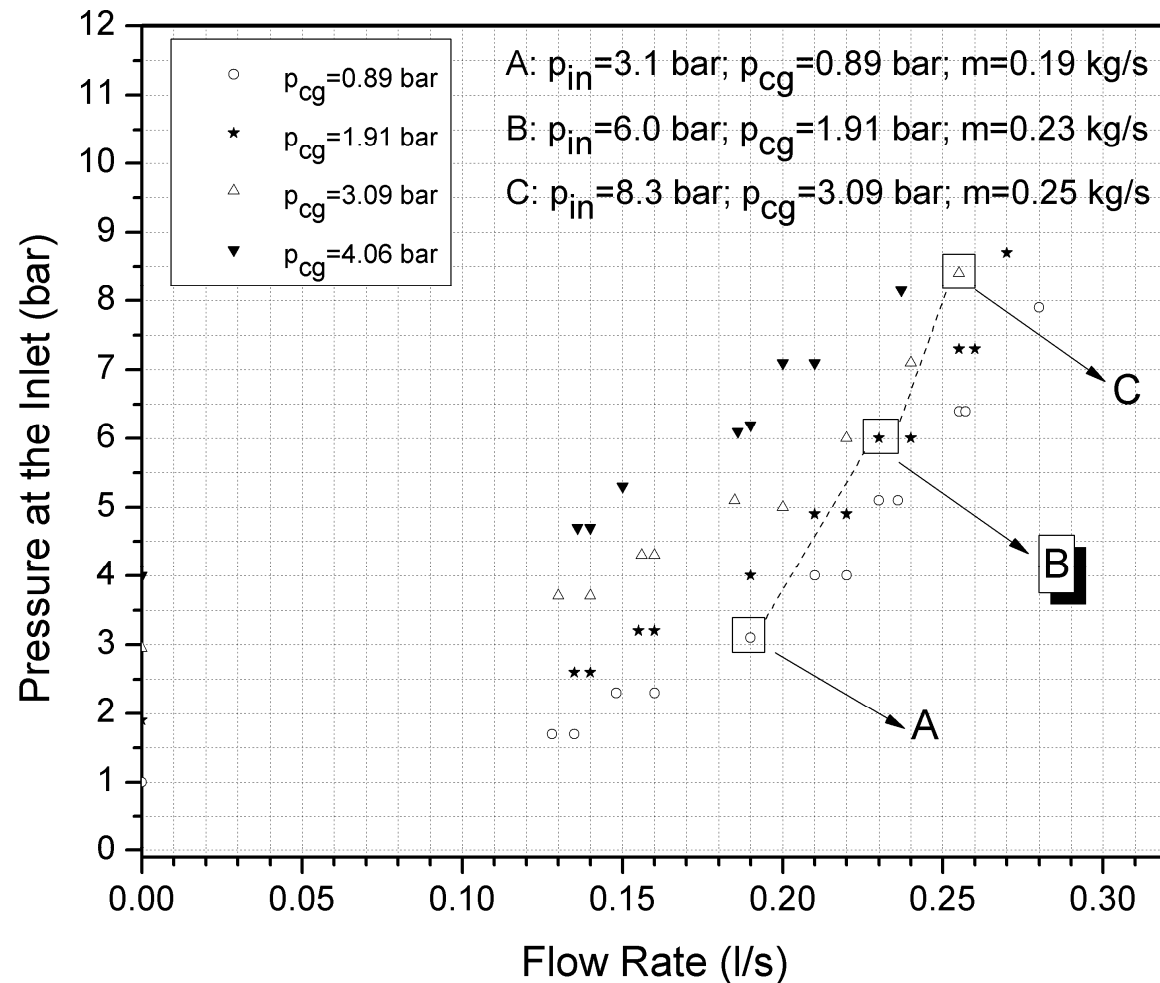
Limit of Cavitation

Pressure of the inlet as function of the flow rate for different pressures of the cover gas .

Capital letters indicate where incipient cavitation was detected

Higher pressure helps to avoid cavitation!

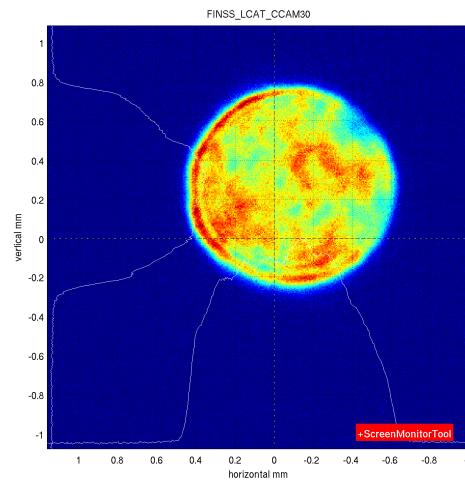
**Operation now:
@ 0.07 m/s**



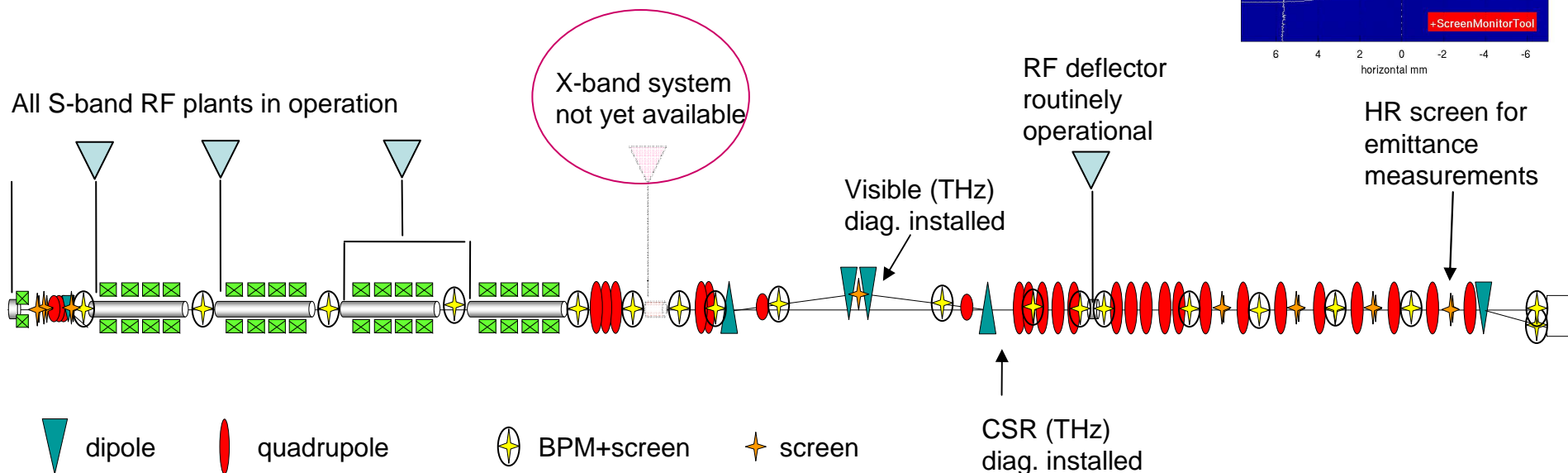
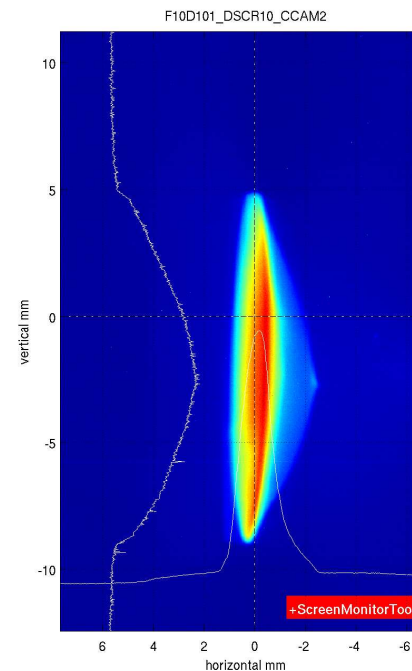
SwissFEL Injector Test Facility: Status



**Pulsar laser
(transverse profile)**



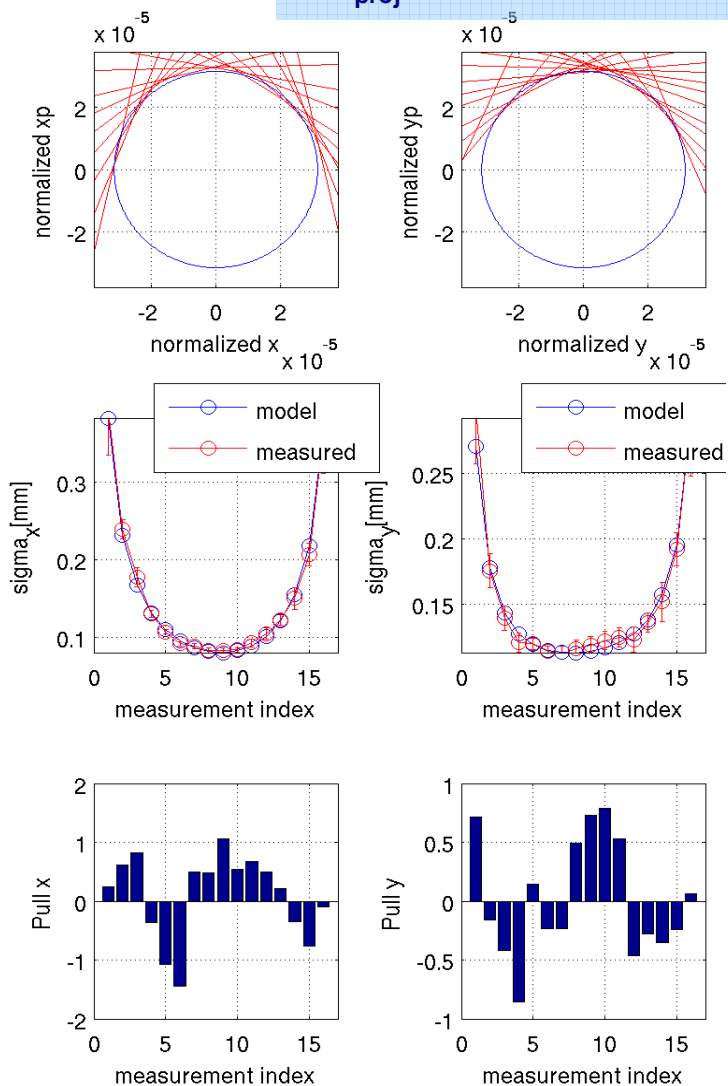
Beam energy ≥ 250 MeV



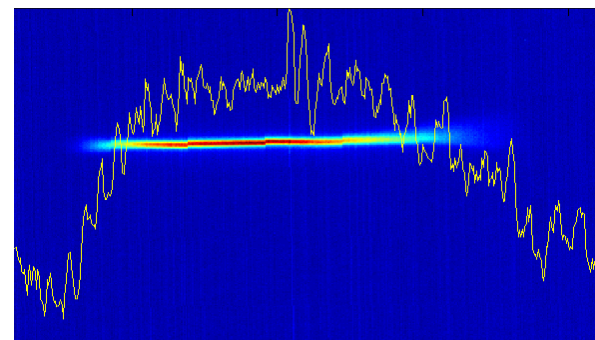
Measured Emittances at 200pC

Projected emittance

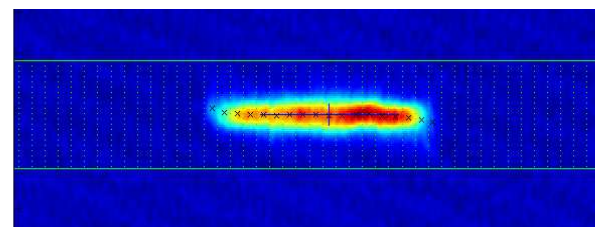
$$\begin{aligned}\epsilon_{\text{proj}}(x) &= 0.45 \text{ mm mrad} \\ \epsilon_{\text{proj}}(y) &= 0.44 \text{ mm mrad}\end{aligned}$$



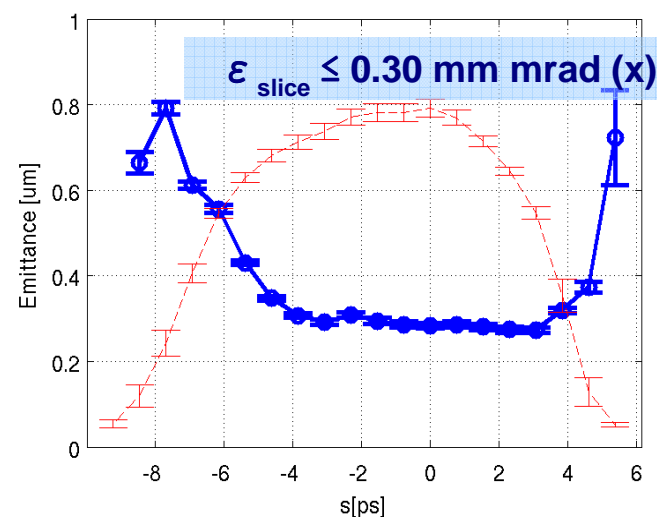
Slice emittance



streak



slice



SwissFEL C-band Teststand: Status

✓ 50MW/100Hz C-band Klystron from Toshiba commissioned

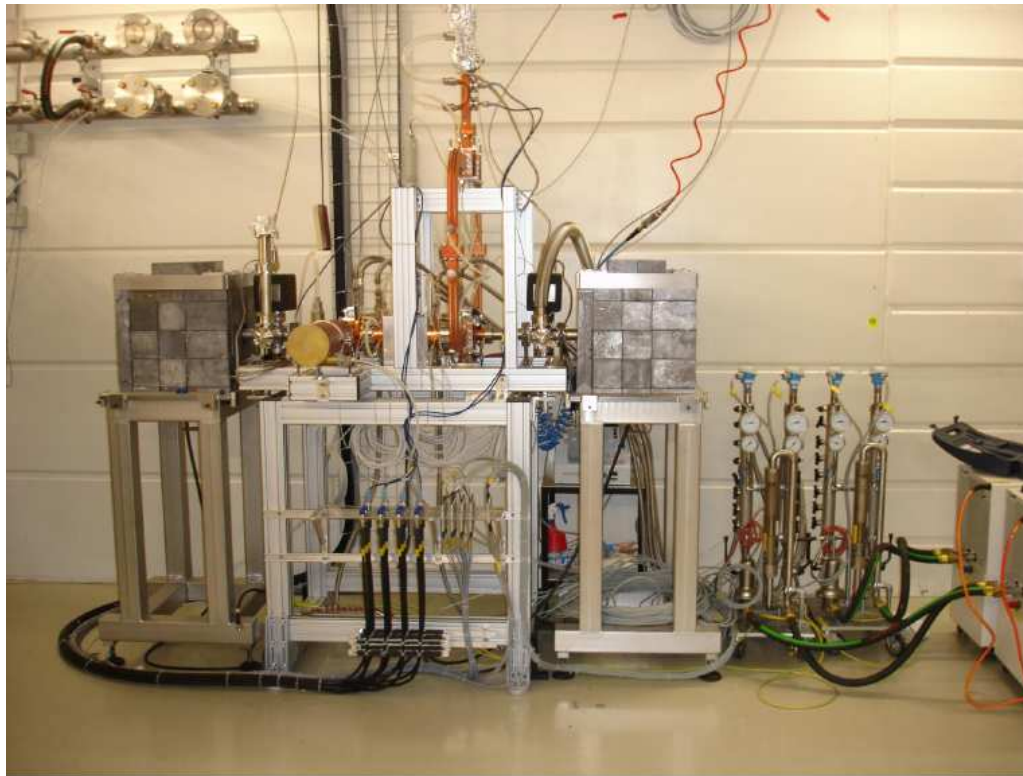
✓ 3 short structures tested (up to 57MV/m)

✓ Acoustic measurement for localization of break downs

□ Prototype collaboration modulator commissioning started

□ Collaboration with Swiss industry for structure fabrication initiated

□ Prototype pulse compressor in fabrication



Ultra-precision cup:



Thank you for your attention!

