

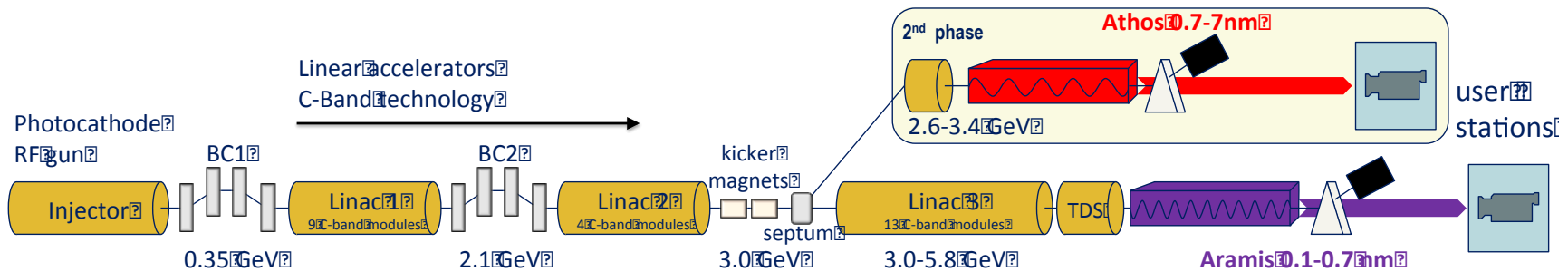
PAUL SCHERRER INSTITUT



Riccardo Zennaro:: Paul Scherrer Institute

Robotic disk stacking for the production of RF structures

TTC2020, CERN, 06/02/2020



ARAMIS

Hard X-ray FEL, $\lambda=0.1-0.7$ nm

Linear polarization, variable gap, in-vacuum undulators

Inaugurated in December 2016

Operation modes: SASE & self seeded

ATHOS

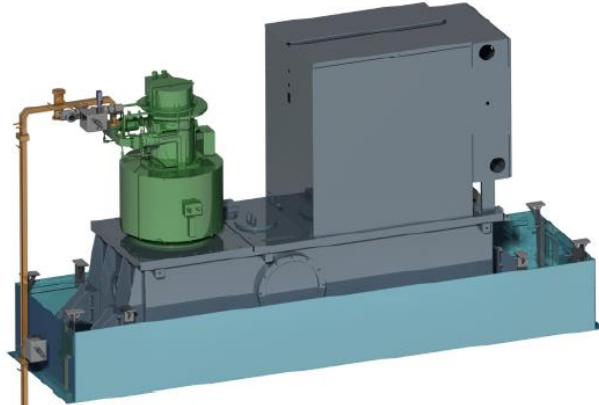
Soft X-ray FEL, $\lambda=0.7-7.0$ nm

Variable polarization, Apple-X undulators

Under installation

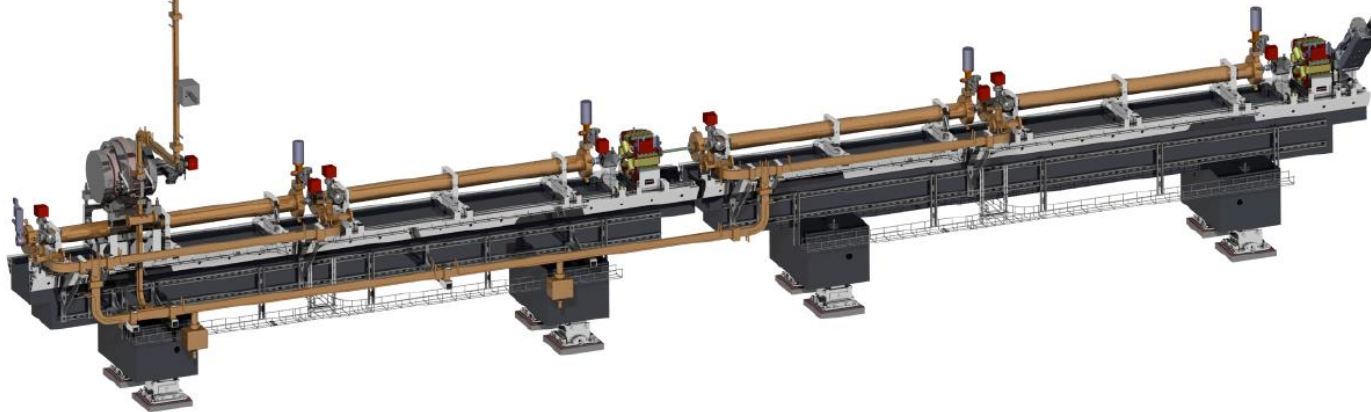
Operation modes: SASE & self seeded

C-band Module



Module's component

<input type="checkbox"/> Structure production	x 104	in house
<input type="checkbox"/> Cell production	x ~12000	VDL ETG CH
<input type="checkbox"/> J-couplers production	x 208	VDL ETG
<input type="checkbox"/> Pulse compressor "BOC"	x 27	in house
<input type="checkbox"/> Waveguide production		MHI-MS
<input type="checkbox"/> Module assembly	x 26+1	in house

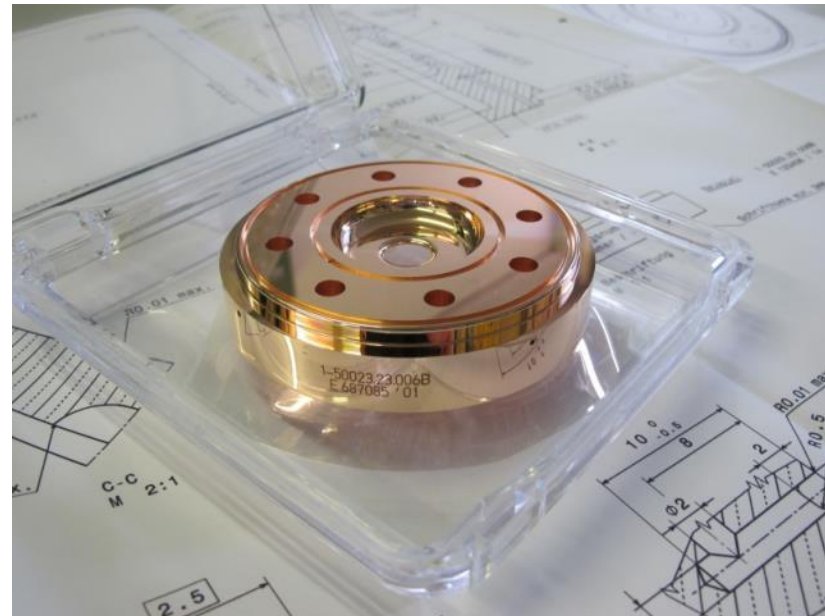
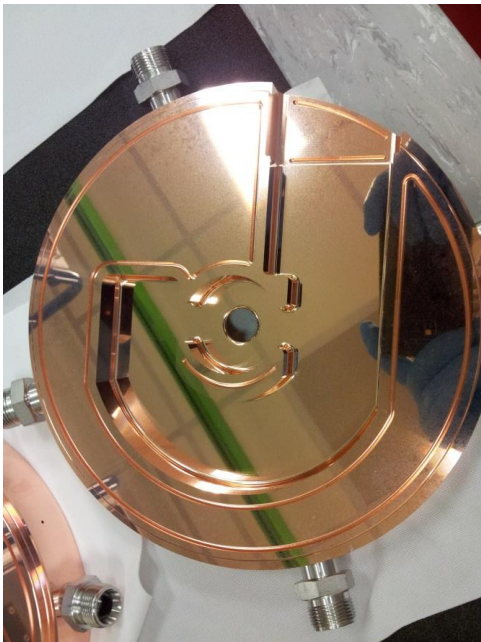


SwissFEL accelerating structures

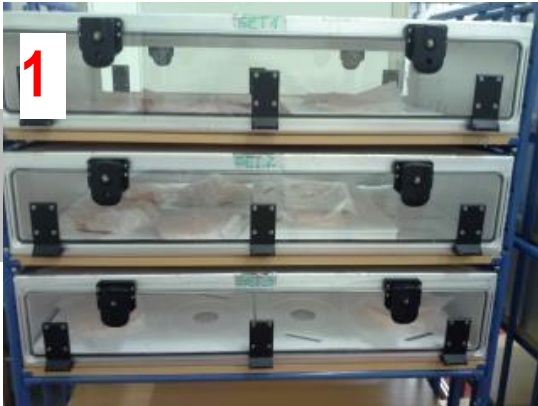
Type	Constant gradient travelling wave
Frequency	5.712 MHz
Phase adv./cell	120°
Length	2m
# cells	113
Gradient	28.5 MV/m
R/Q	7.2-8.7 Ω /m
Q	~10000
V_g	3.1-1.2 (%/c)

Tuning free technology:

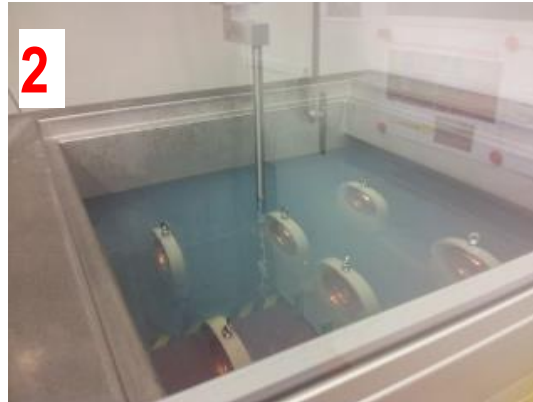
Accelerating structures have been design to be tuning free, i.e. they have been design on frequency without any option of frequency adjustment before and after brazing. Same solution adopted for the pulse compressor BOC



AS production and tuning-free technology



Storage under N2



Cup washing



Disk stacking



Vacuum brazing



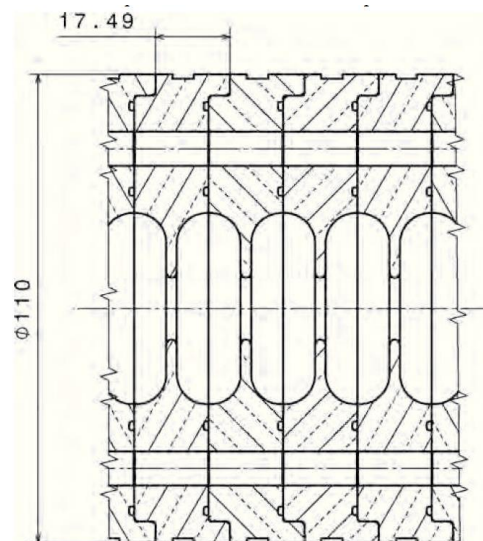
Structure reversed to horizontal position on a temporary girder



Bead pulling

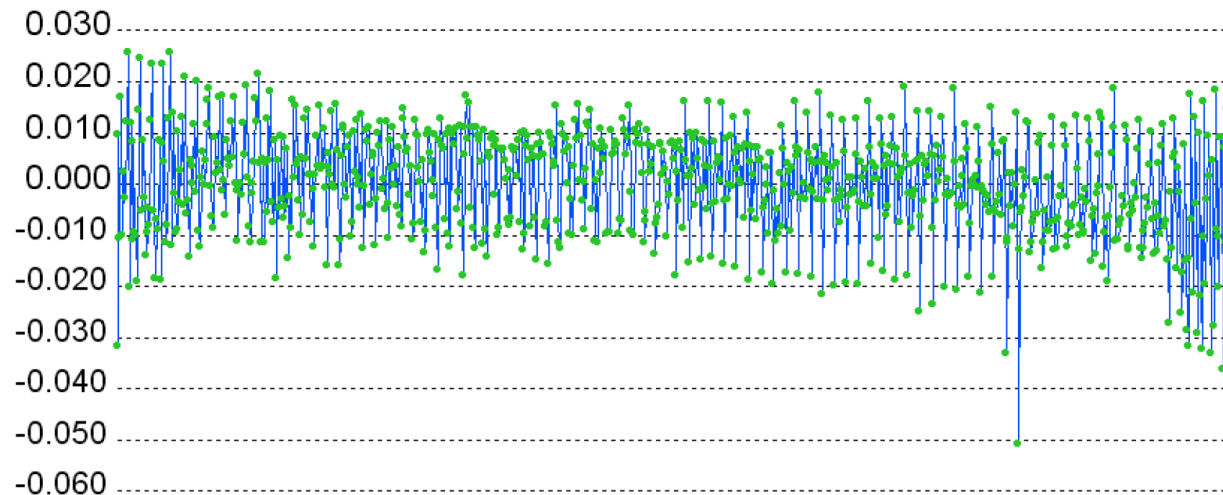
Robot stacking 1

- The cups are machined from 3D forged OFE copper with a tolerance of ± 2 microns by means of a mono-crystalline diamond tool in a temperature and humidity controlled machine
- The cups are vacuum fired at 400 °C before stacking
- We use a KUKA robot type KR 30 (high accuracy) with 2m action radius and repeat accuracy of 5 microns (x,y,z).
- The robot reads the bar code of each cup and verify that the brazing alloy is in place
- The new cup is warmed up to 50 °C, 30 °C warmer than the stack which corresponds to an increased inner diameter of 23 microns.
- Input/output coupler are manually placed (warmed up to 70 °C)



Robot stacking 2

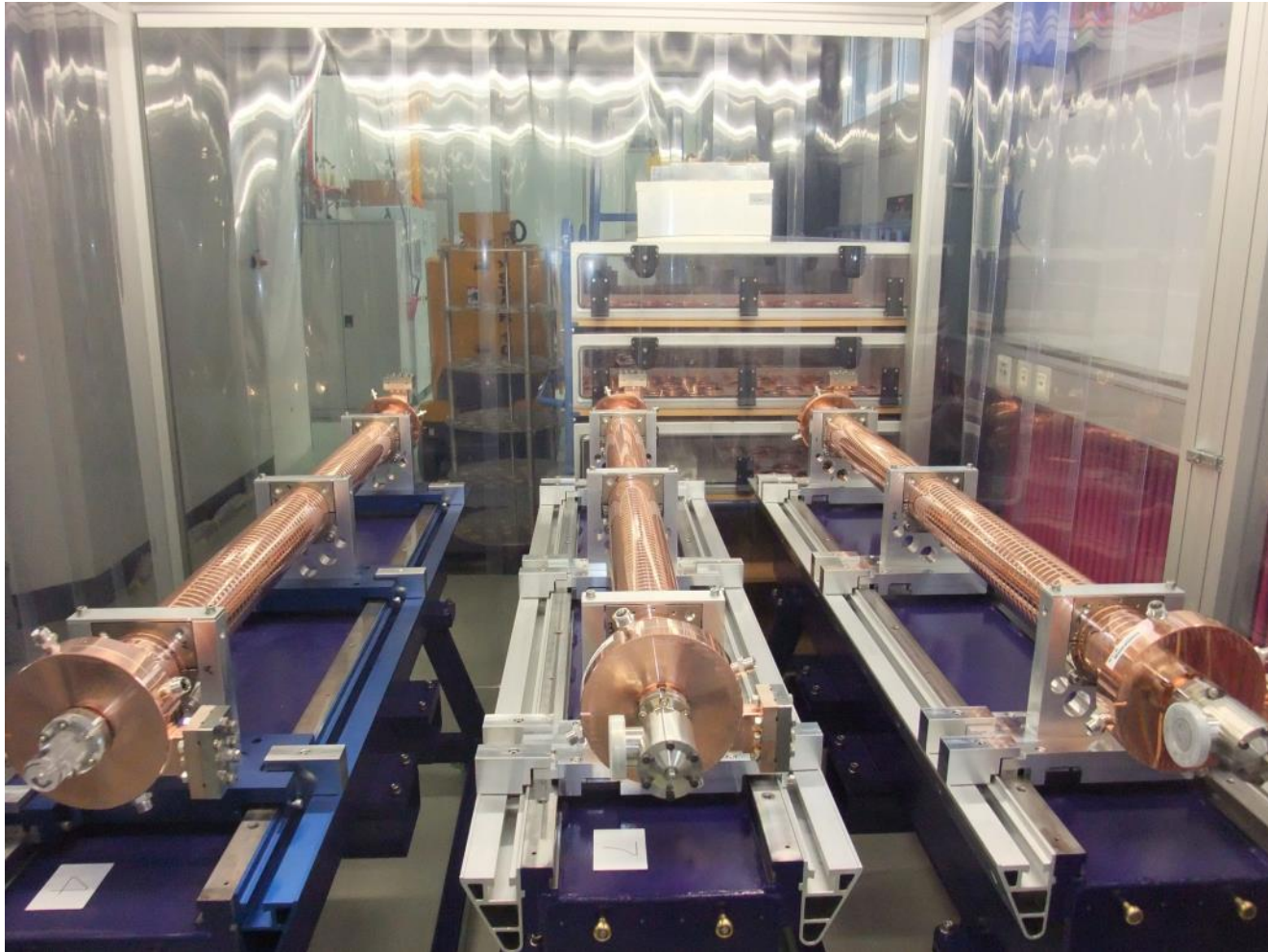
- After 1/3 and 2/3 of the height of the final stack the perpendicularity is checked by means of two claws moving inward and stopping using encoders
- After stacking of the cups and the two couplers two base plates and three bars (Inconel 600) are mounted to fix the stacked components for brazing and move it to the brazing furnace.
- The frame with the stacked cups and couplers behaves like a pendulum to stay perfectly vertical during brazing.
- The brazing is performed at 820 °C and takes more then one day
- Production rate was ~1.3 structure/week
- Results all cups in a 2m structure are inside a 50 microns radius





Robot Stacking video

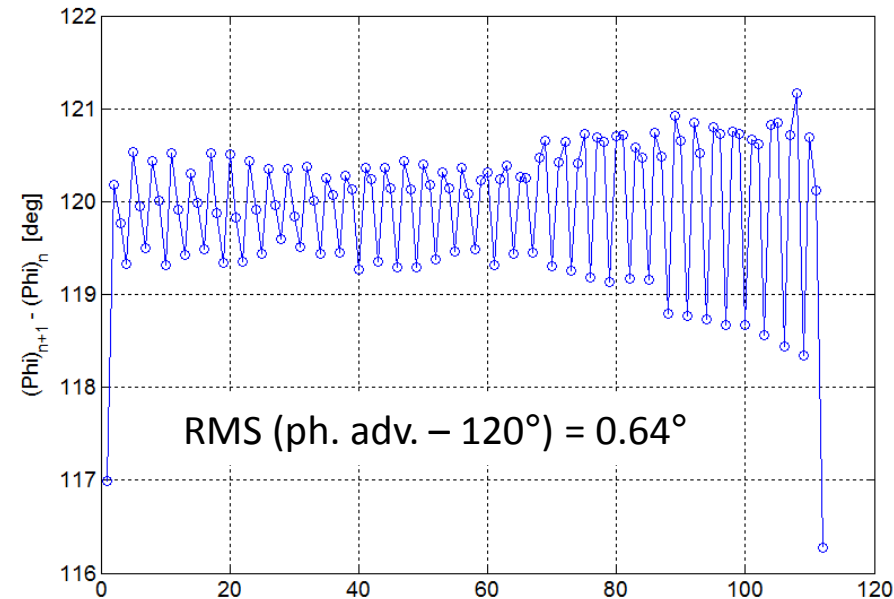
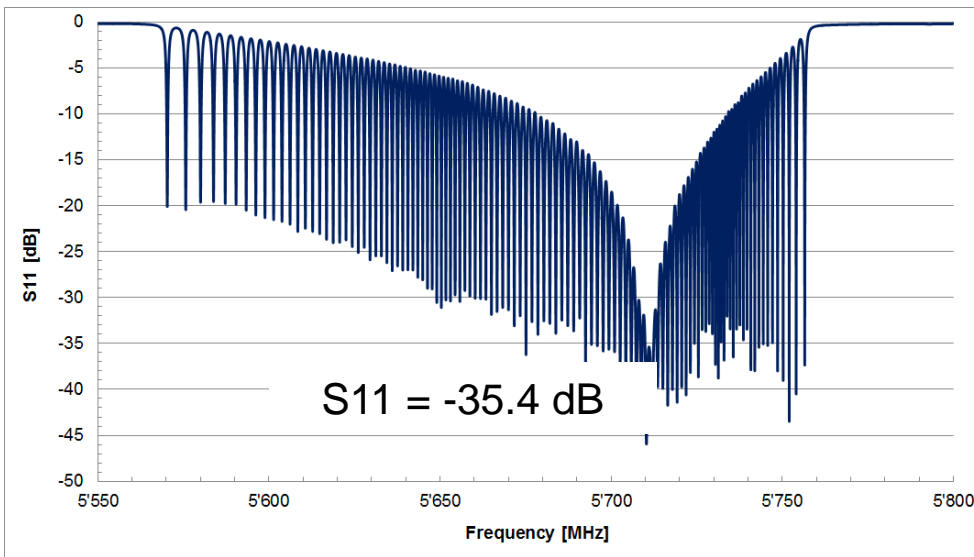
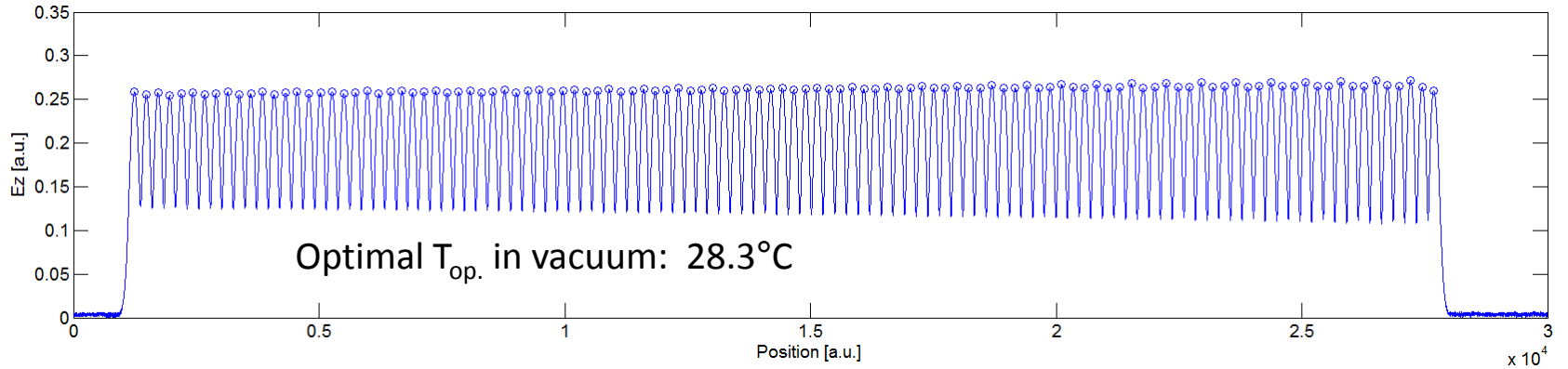
Accelerating structure: the final result



<https://accelconf.web.cern.ch/accelconf/LINAC2012/papers/tupb012.pdf>

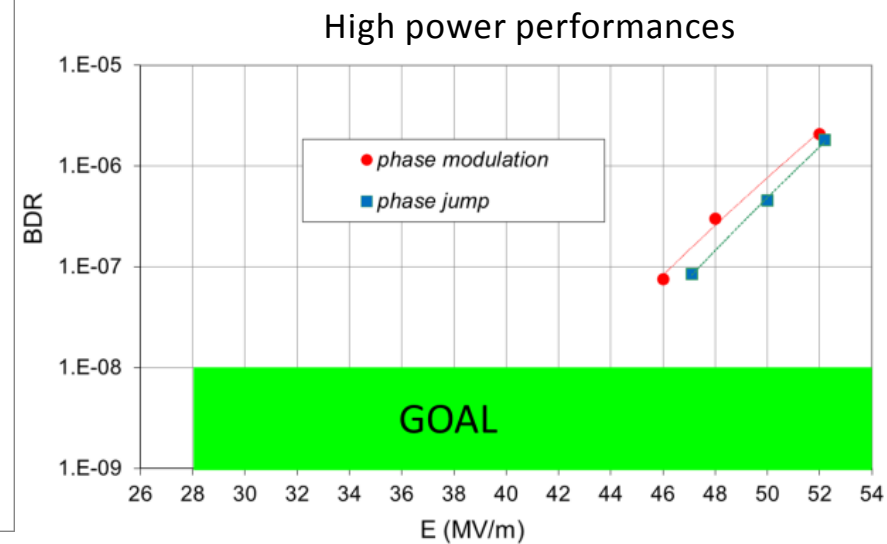
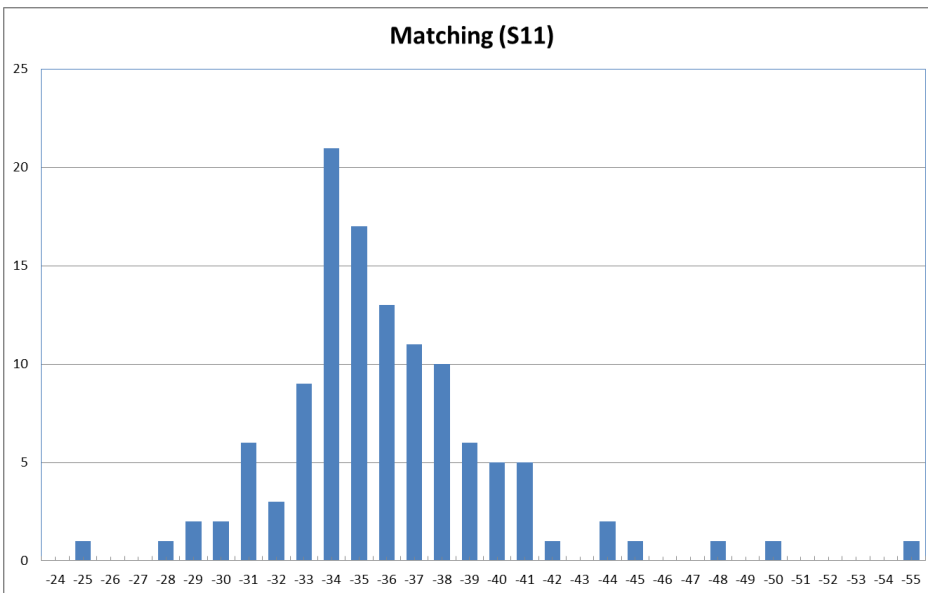
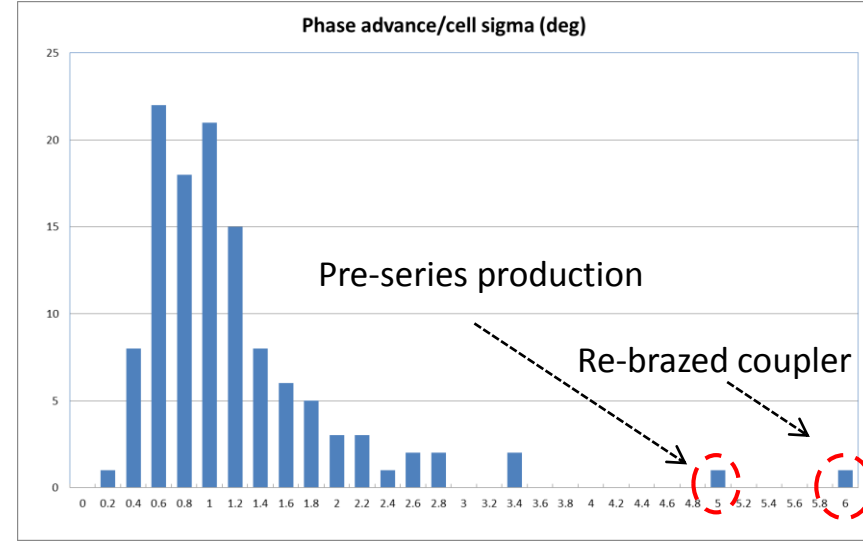
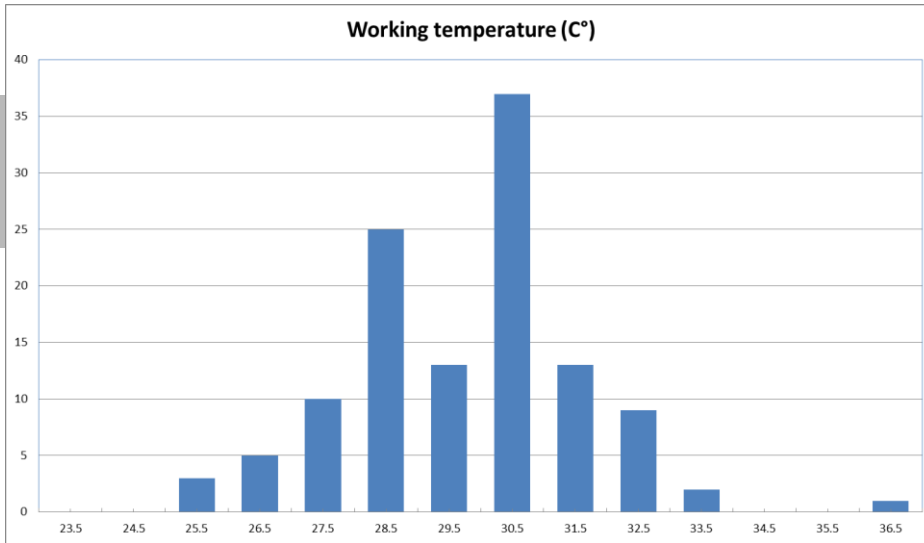
<http://accelconf.web.cern.ch/AccelConf/LINAC2014/papers/mopp119.pdf>

RF measurements: example



N.B. No tuning applied

AC production statistics



Present and future activities

- PSI is making use of part of the know-how developed for the SwissFEL in designing and producing several RF cavities:
 - *Polarix, collaboration between DESY, CERN and PSI to produce several variable polarization X-band deflecting cavities*
 - *XBOC X-band BOC pulse compressor designed and produced at PSI and successfully tested at CERN*
 - *CLIC test structures: PSI produced two X-band cavities successfully tested at 100 MV/m at CERN*
 - *Two S-band 3m accelerating structures under production at PSI in the framework of an ELETTRA-PSI collaboration*

All these activities make use of the tuning free technology but there is no use of the robot stacking technique because of the limited production

Combination of tuning free and robot stacking technology provides excellent results in terms of field quality and performances

- ✓ Design codes and UP machining offer nowadays the possibility to produce normal conducting accelerating structures and high power components directly on frequency
- ✓ SwissFEL gave us the possibility to prove this technology that has been used also for higher frequency (tuning free at X-band)

