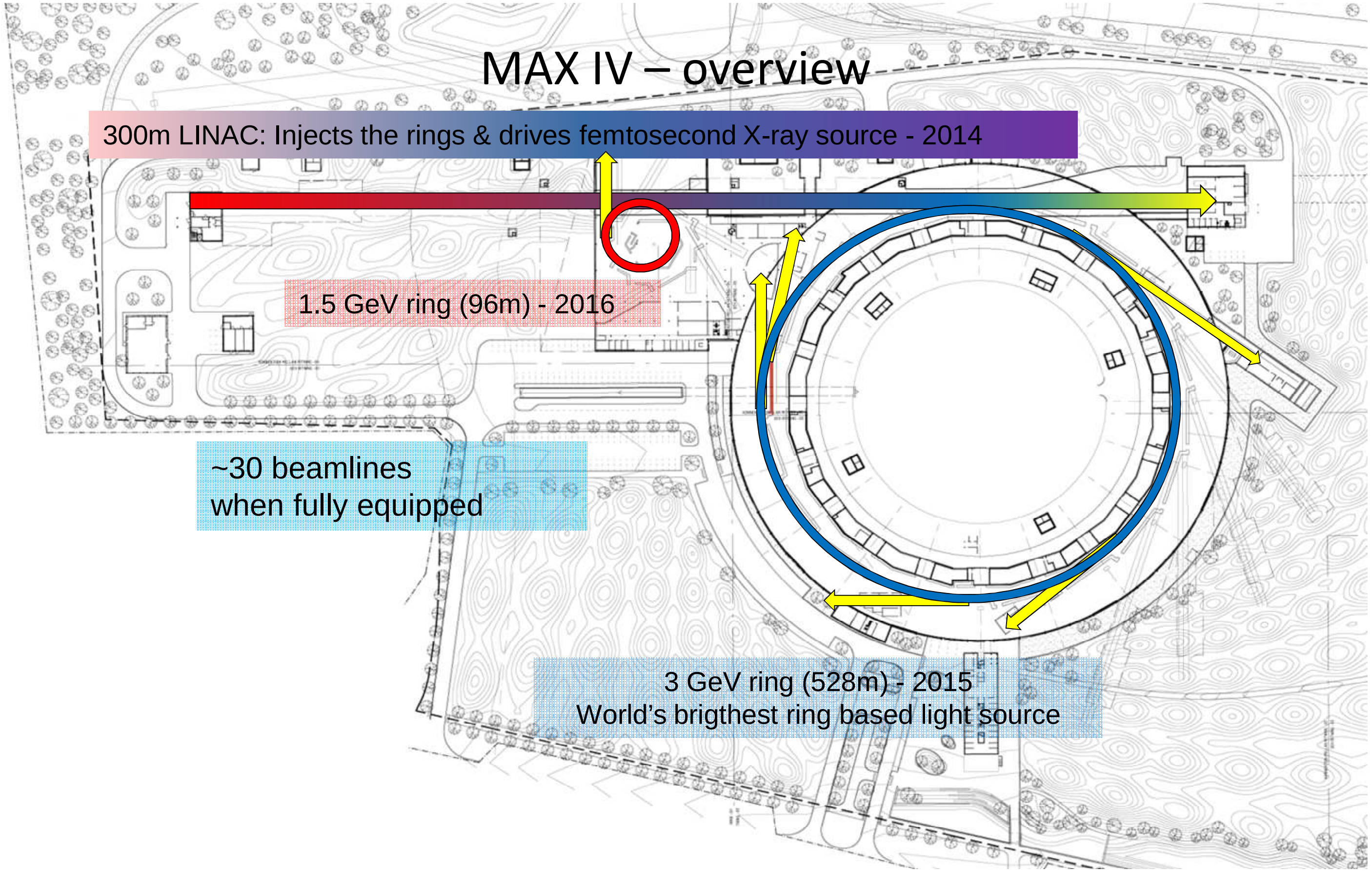
Status of the MAX IV RF systems

Outline

- MAX IV overview
- Status at construction site
- Linac
- Main cavities
- Harmonic cavities
- Digital low level RF

MAX IV – overview



Construction site

11 June - Less than a year to installation, finishing touches to first part of linac tunnel

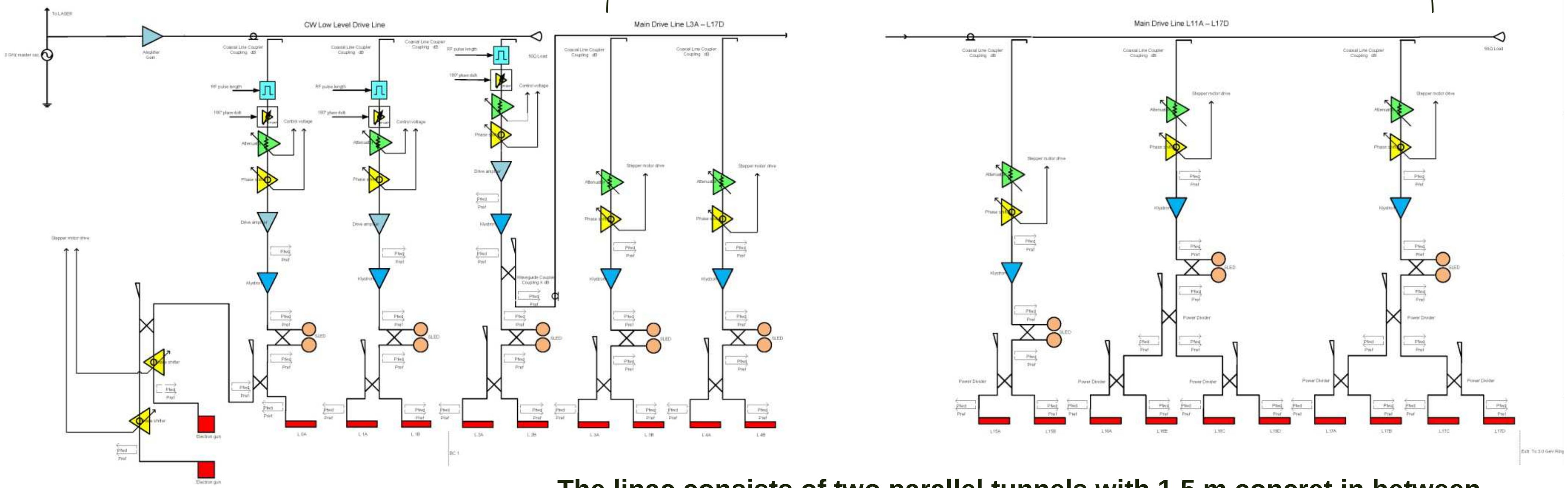
Max IV linac design strategies

- High temperature stability
- RF phase follows the linac elongation
- Modulators with low voltage pulse to pulse jitter
- Minimize output power variations by running the klystrons saturated

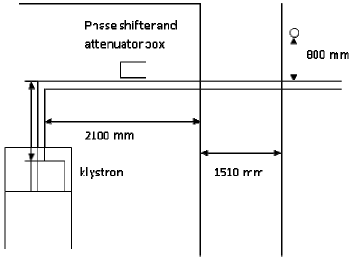
Max IV linac RF system

Random voltage and phase variationstions are reduced by the square root of the number of klystrons

Main Drive Line (MDL) feeding 15 klystrons



Klystron tunnel Concret Linac tunnel



The linac consists of two parallel tunnels with 1.5 m concret in between. The wave velocity in an air-filled transmission line is almost the same as the speed of the electrons in the linac.
Length variations of the linac tunnel will automatically be compensated for since the MDL, consisting of a rigid 1 5/8" coaxial transmission line with sliding joints, also will follow this length variations.

Linac RF unit

❖S-band RF Unit parameters

Nr	Parameter	Unit	Value
1	RF frequency	MHz	2998,5
2	Max. Peak RF Output Power	MW	35 - 37
3	Max. Klystron Average RF Power	kW	16 -18
4	RF flat top pulse width variable	µs	0 to 4.5
5	Voltage Pulse width variable (80%)	µs	2.5 to 7
6	Pulse Repetition Frequency variable	Hz	0 to 100
7	Flat top ripple or droop	%	± 0.5
8	Pulse to pulse voltage stability	%	± 0.01
9	Voltage pulse to pulse jitter	ns	≤ 6
10	Modulator Electric efficiency	%	>80
11	Klystron efficiency	%	>40
12	RF output flange		LIL

PULSED KLYSTRON AMPLIFIER E37310

TOSHIBA E37310, S-band high-power pulsed amplifier klystron, is designed for linear accelerators.
The E37310 delivers 37 Mw peak output power with a power gain of more than 48.5 dB and with an efficiency of more than 40%. (*1)

The electron beam is focused with the electromagnet VT-68922.

An "M"-type dispenser cathode with high reliability promises long tube life.

RF Phase change 3-4° /%Vk

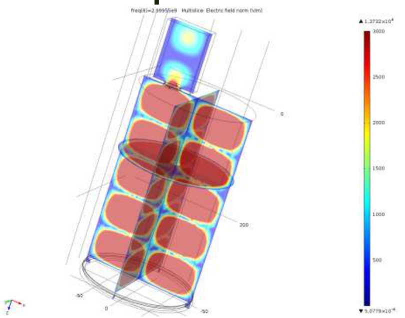
Measured pulse to pulse voltage variation < 10^{-4} rms

<0.04 ° RF phase pulse to pulse jitter

Pulse compression (SLED)

The Stanford Linac Energy Doubling (SLED) is used to increase the peak power for a given total pulse energy. This is obtained by charging an overcoupled (β≈6) high-Q cavity by the RF generator.

Waveguide input (iris) coupler

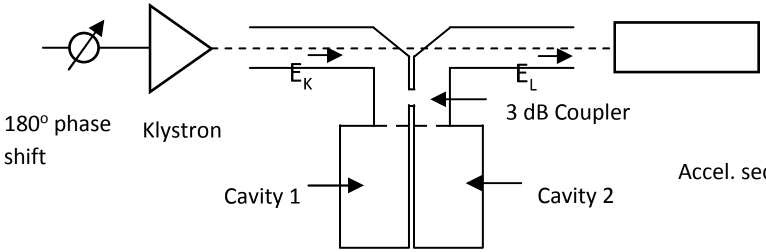


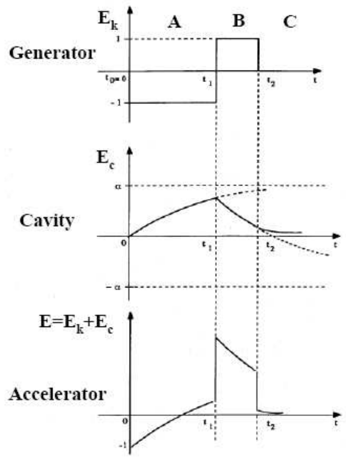
The accelerating gradients integrated over a small portion of the klystron pulse durtion is almost doubled.

$\Delta\varphi/\Delta E = 8°/°C$

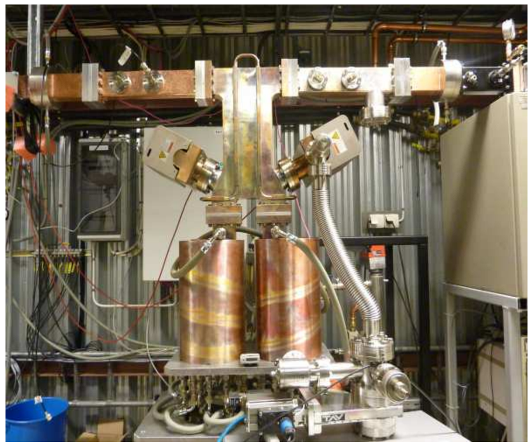
Coolingwater temperatur stability ± 0.02 °

RF phase stability < ± 0.2°

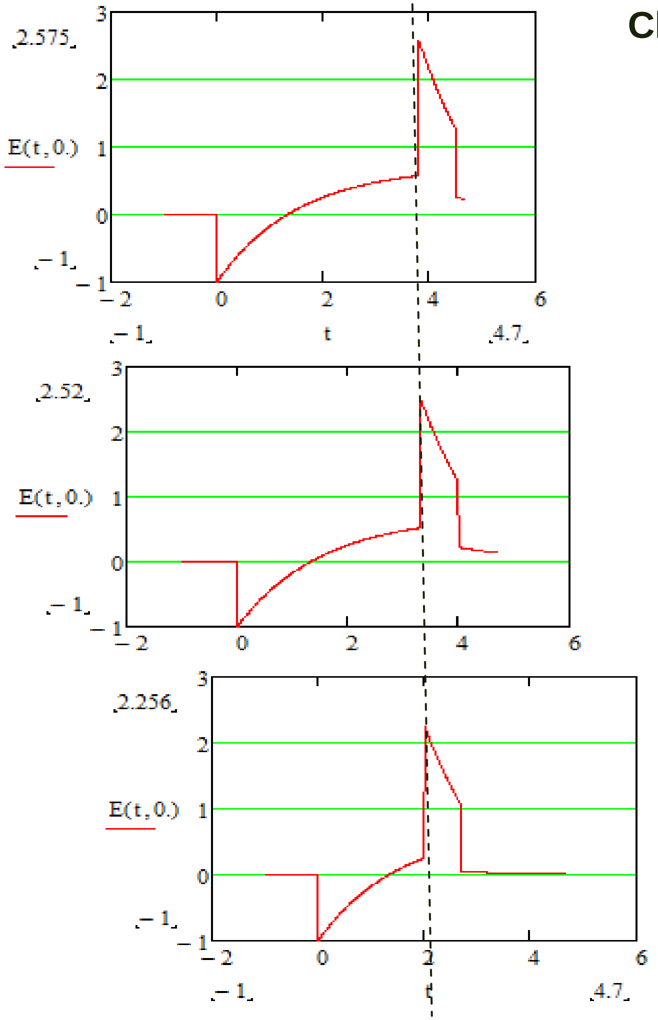




TE_{015}, $Q \approx 10^5$



Output power from SLED is adjusted by varying the charging time



Charging time

3.8 µs

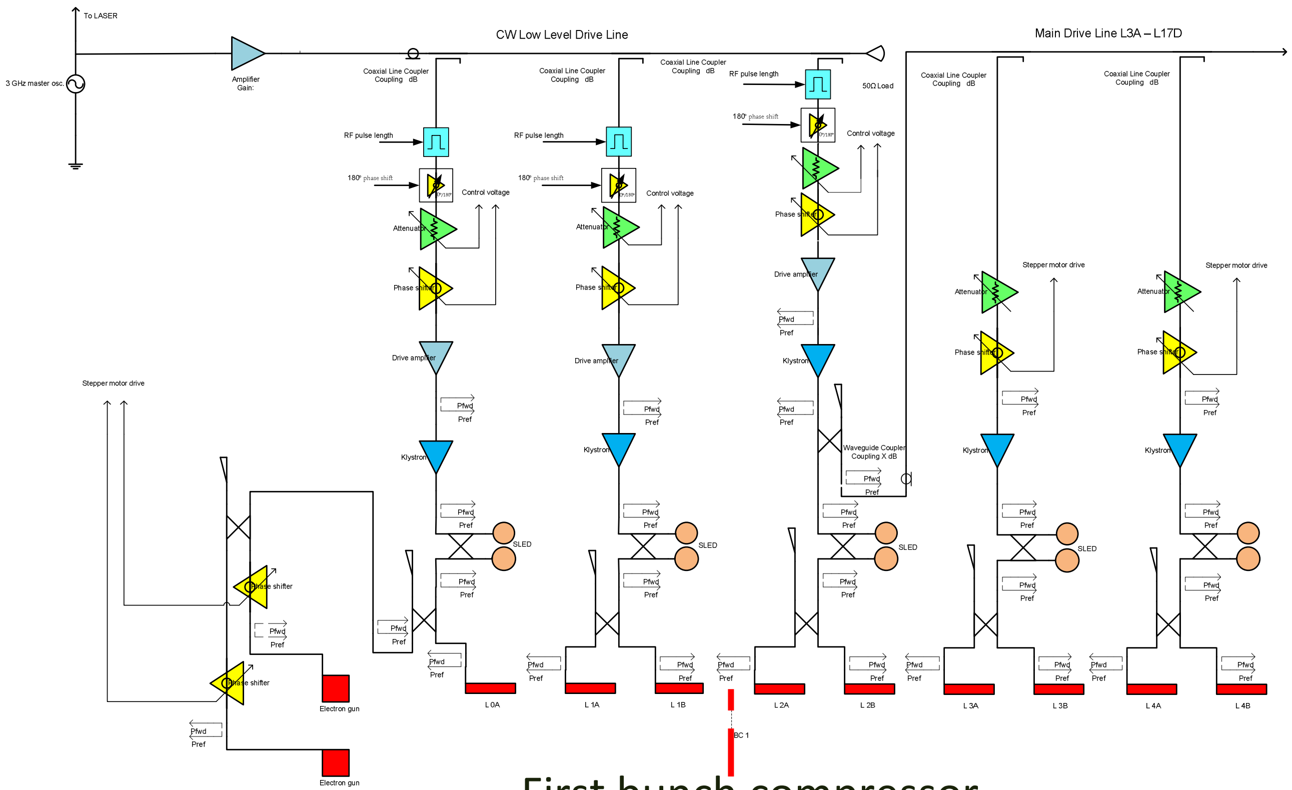
3.3 µs

2.0 µs

The klystrons are running at konstant voltage to maintain a constant RF phase at the output. In order to reduce klystron output power variations due to variations in the input power they are run in sturation mode.
The output power from SLED is adjusted by varying the charging time.

SLED data
β=6
$Q_o=10^5$

Knobs



First bunch compressor

Availabe adjustments, the first three RF units

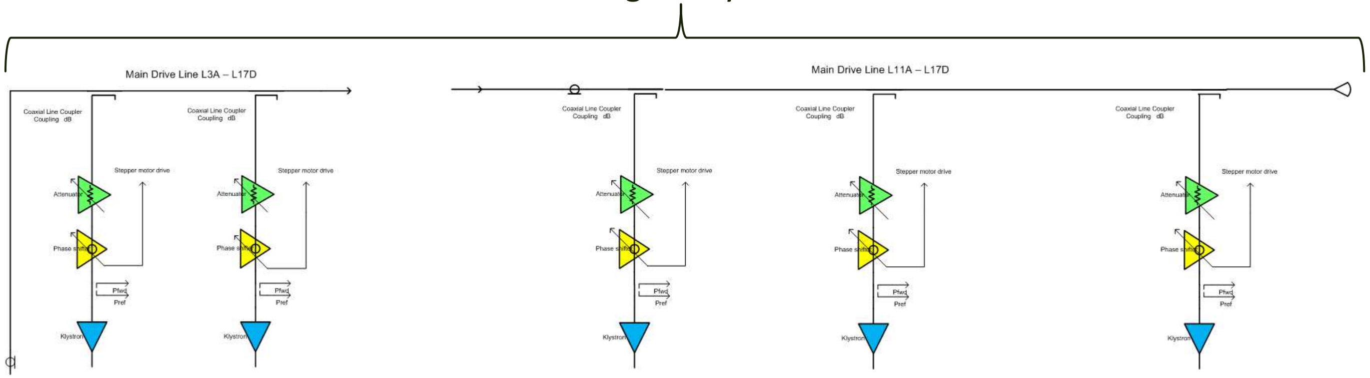
1.LINAC input power (SLED charging time)

2.LINAC phase

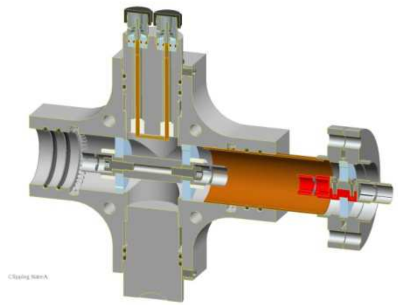
These kobs will be used for phase and energy feedback

MDL

MDL feeding 15 klystrons



Input RF power from the third klystron 90 kW



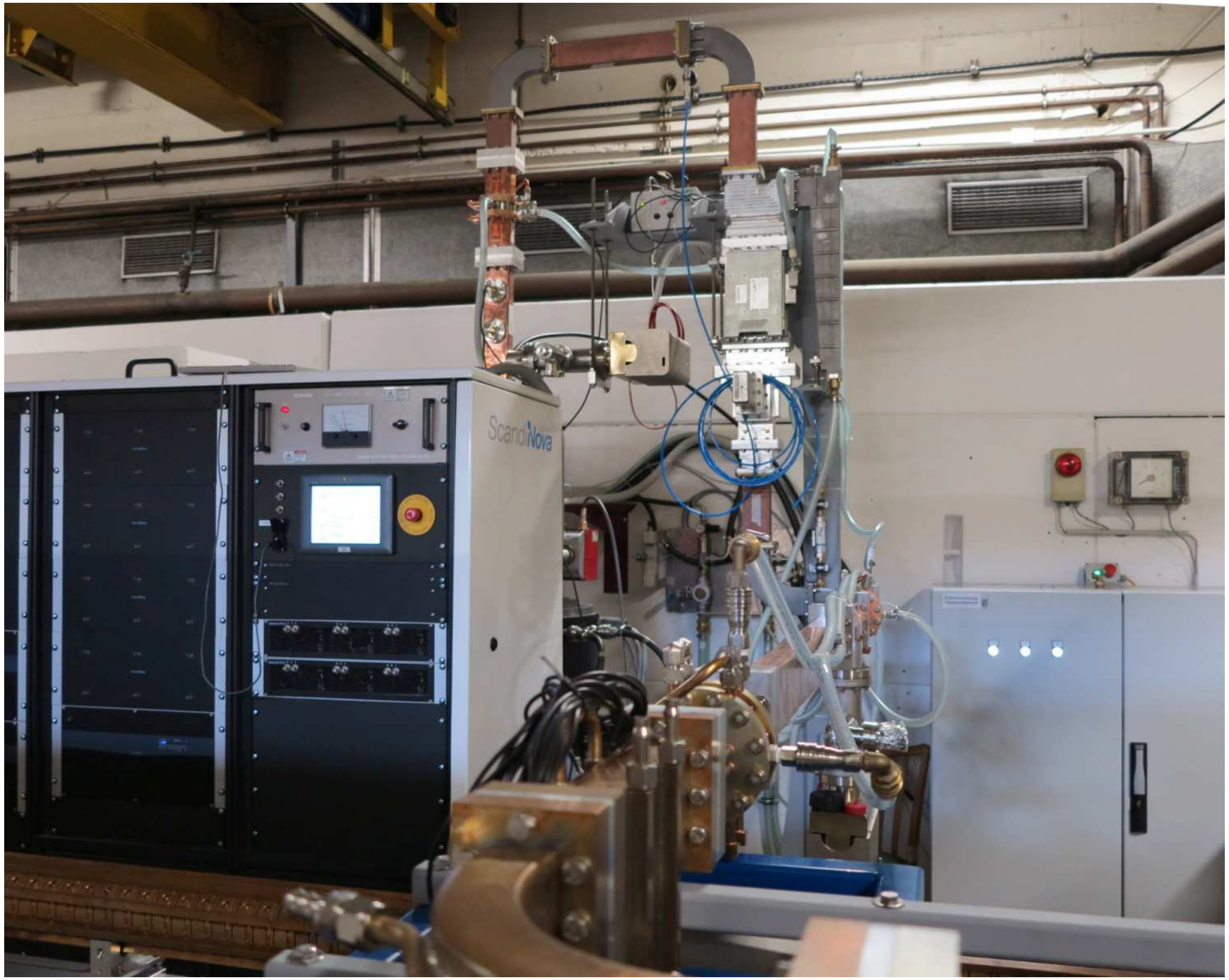
The transmission line pressure(nitrogen) is regulated to compensate for propagation variations due to pressure change

Adjustable directional couplers
Fixed to the linac tunnel wall at each accelerating section
Sliding joints
Connected together with pressure regulated 1 5/8” EIA rigid line

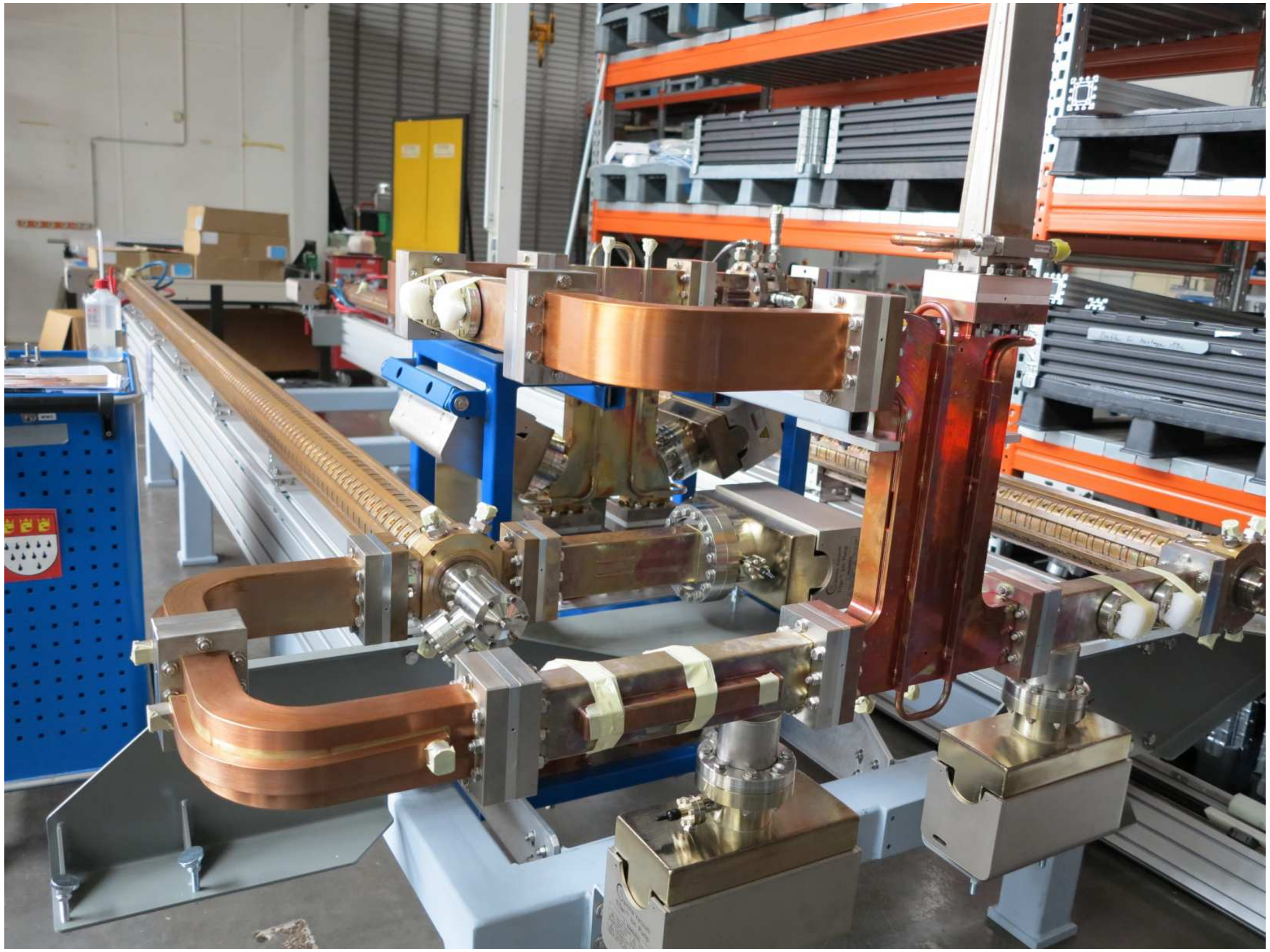
Linac

- Total length 275 m
- 18 S-band RF units (klystron+ solid state modulator) supplied by Scandinova, Uppsala, Sweden. Contract signed 11/8/2010. The 18th and last of all RF units were delivered in August 2012.
- Toshiba klystron E37310
- 18 acceleration units, supplied by RI Research Instruments GmbH, Bergisch Gladbach, Germany, consisting of SLED (18 units), power devider (20 units) and Linac sections (39). They are delivered conditioned. Contract signed 15/07/2010. Fourth acceleration unit is conditioned.
- Waveguide system supplied by IHP (Institute of High Energy Physics), Beijing, China. Contract signed April 2012. Final delivery January 2013.
- Installation is expected to begin May 2013

Linac section conditioning (Bonn)



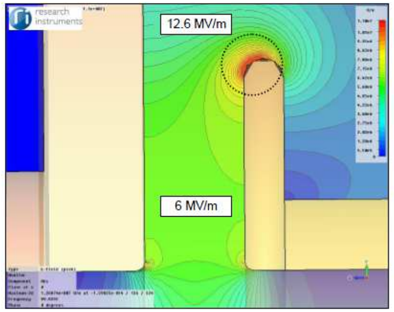
Linac section conditioning (Bonn)



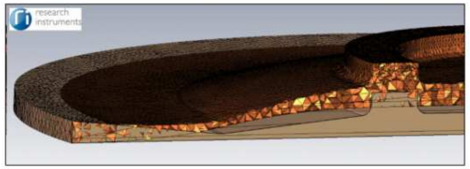
RF Systems 3 and 1.5 GeV Rings

- Main Cavities (100 MHz Capacity loaded, Max-lab design):
  - Contract Signed with RI in Feb 2011
  - Cavity Design Review Meeting June.
  - Pre-series cavity delivery according to contract: December 2011.
  - 120 kW Power couples ordered.
  - First delivery according to contract: Feb 2012.

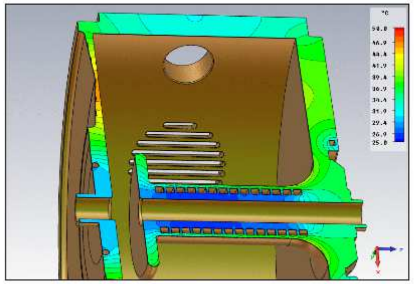
Tuning Mechanism



RF



Tuning plate



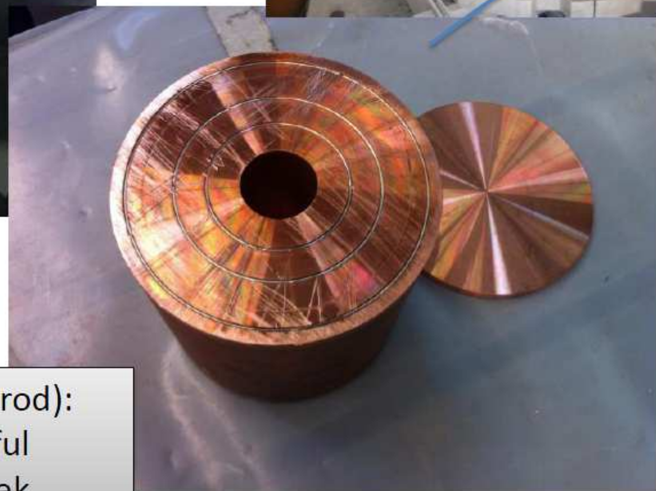
Thermal

Pre-series Cavity

Production Status

research instruments

Pre-milling of the mantle is finished,
Final milling this week



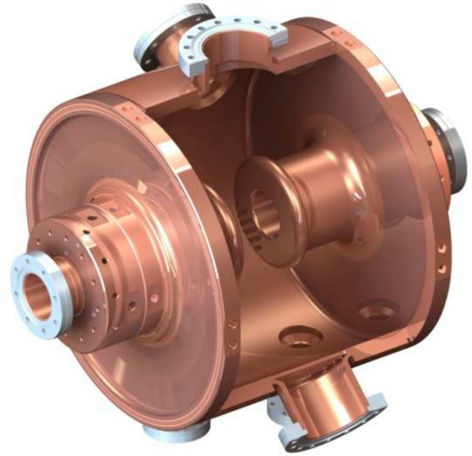
Braze test piece (inner rod):
1st braze stage successful
2nd braze stage this week

Pre-series Cavity

- Pre-series RF cavity delivered May 29th. ***Purchase of long lead items (copper) approved.***
- Pre-series High Power Coupler delivered in June
- Cavity Conditioning stand ready: Conditioning during October/November.
- Power plant specification/Call for Tender in end of October.
- Low level RF upgraded (diagnostics) with second FPGA and tested in the MAX II storage ring with two cavities in July.

RF System – Harmonic Cavity

- Prototype Landau Cavity construction successfully finished at RI.
- Mechanical assembly done at Max-lab. Low Level RF tests at MAX-lab early October 2011
- Tests with Beam on going at MAX III. Jonas Breunlin will present the results.
- RI will manufacture five 300 MHz Landau cavities from drawings supplied by MAX-lab.

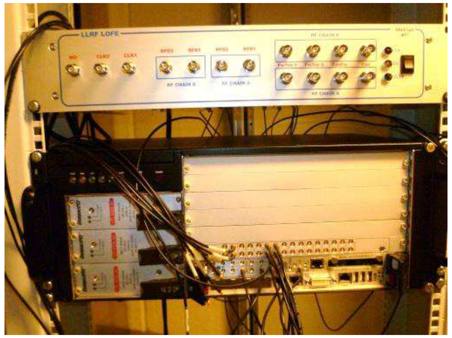


f = 300 MHz
Practice:
Rsh = 5.6 Mohm
Q = 21000

Digital Low Level RF

Design by A.Solom

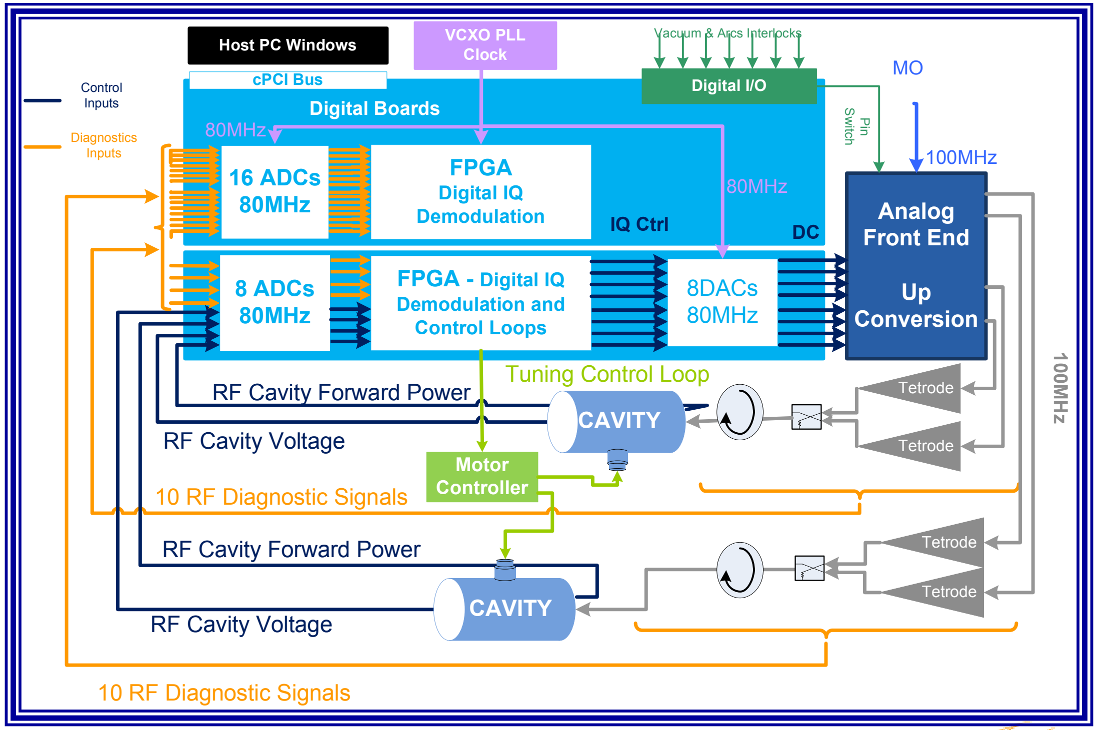
- Prototype Assembled and Tested at MAX-lab



	Resolution	Bandwidth	Dynamic Range
Amplitude Loop	< 0.5% rms	< 10kHz	30dB
Phase Loop	< 0.5° rms	< 10kHz	360°
Tuning	< ± 1°	< 1kHz	< ± 75°

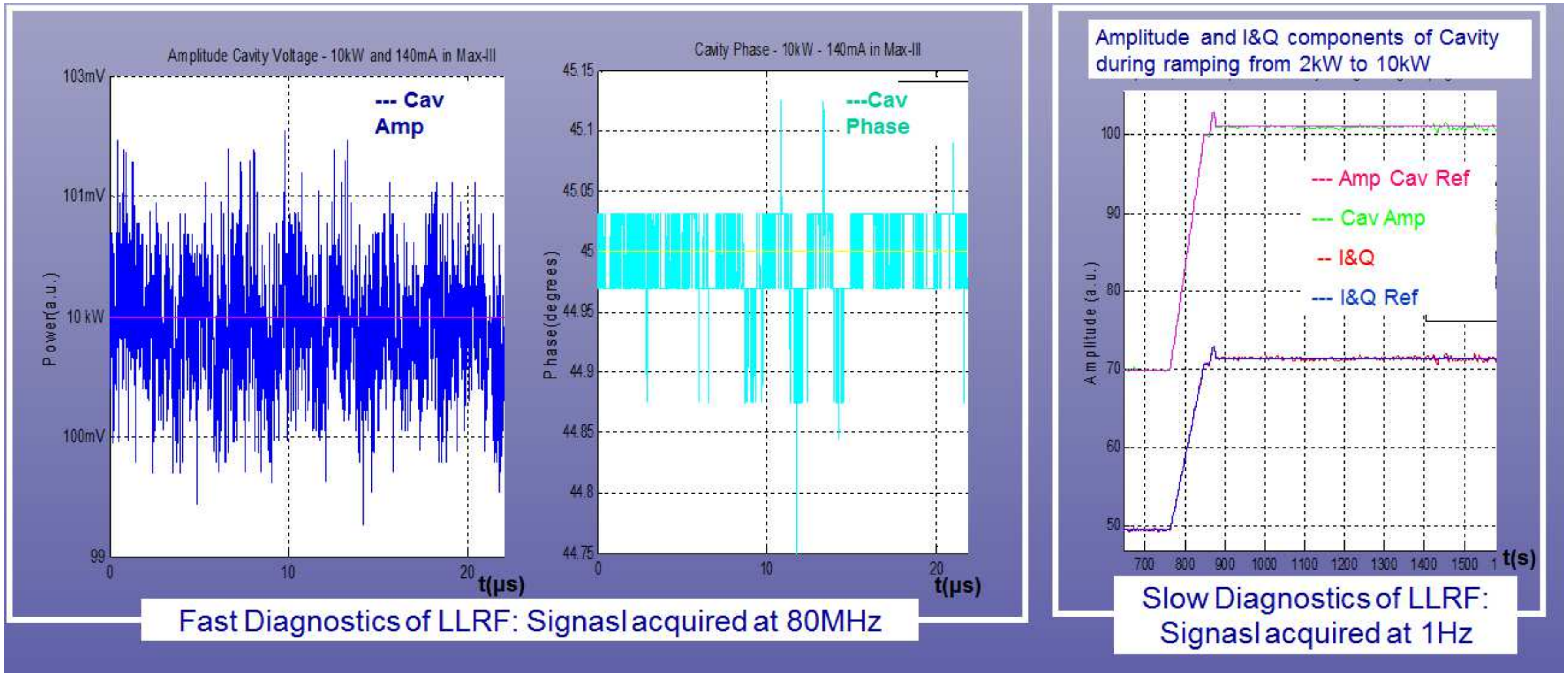
- First Successful tests with Beam at MAX-III in September 2011.

- 200 mA ramped with voltage and frequency loops engaged.



RF Systems: LLRF Test Results

	Loop resolution at 2kW	Loop resolution at 10kW
I&Q Cavity Voltage	0.12 % rms	0.14 % rms
	2mVpp	2.5mVpp
Amplitude Voltage	0.48% rms	0.5% rms
	2.5mVpp	3mVpp
Phase	0.24º rms	0.3° rms
	0.3ºpp	0.5°pp



Fast Diagnostics of LLRF: Signasl acquired at 80MHz

Slow Diagnostics of LLRF: Signasl acquired at 1Hz

Thanks for your attention
Questions?