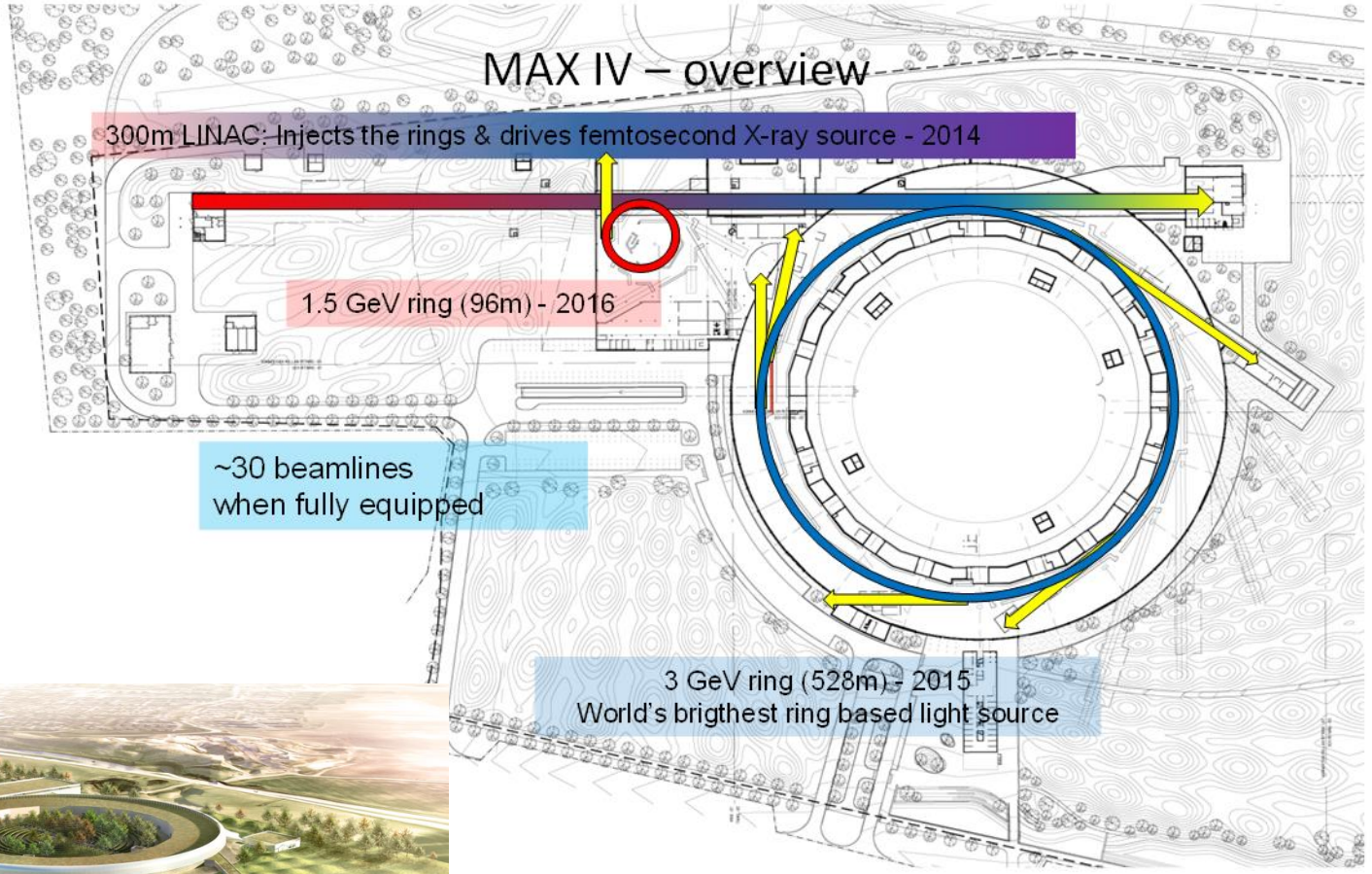
Status of the MAX IV RF systems

Outline

- MAX IV overview
- Status at construction site
- MAX IV - Linac
- MAX IV - Ring RF systems
- Ring RF – Cavities
- Ring RF – Power plants
- Digital low level RF
- Chopper for ring injection



Inauguration June 21, 2016

Aerial View of the MAX IV Site

130903

Photo Perry Nordeng 140821

Inside the 3 GeV building

The experimental hall with the Biomax experimental hutch

Photo Annika Nyberg 140908

Ring tunnel Photo Annika Nyberg 140828

MAX IV Linear Accelerator

Klystron gallery

Photo Annika Nyberg 20130813

Linear accelerator

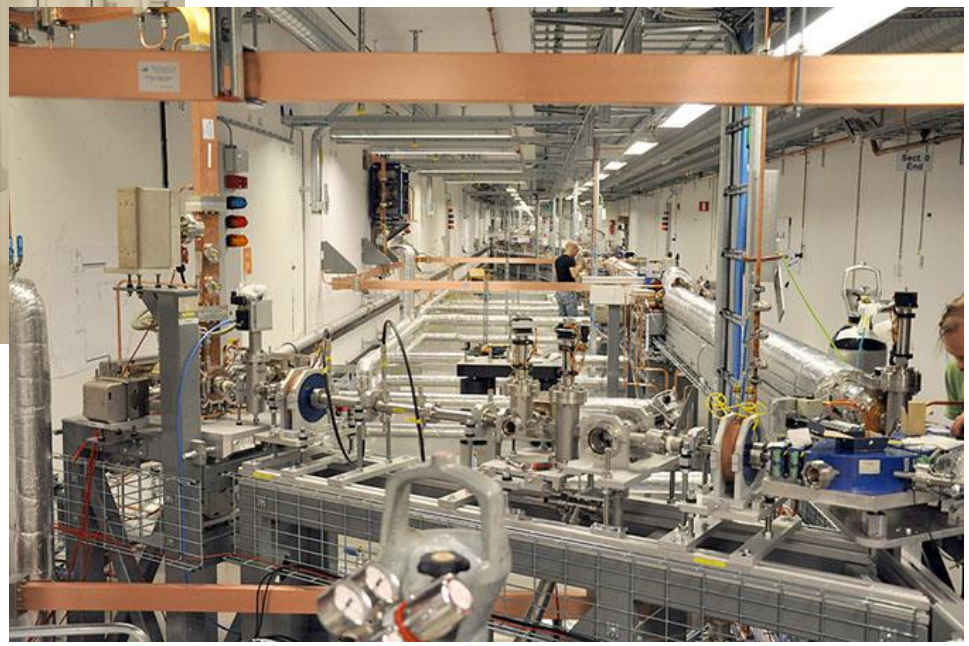


Photo Annika Nyberg

MAX IV Linac

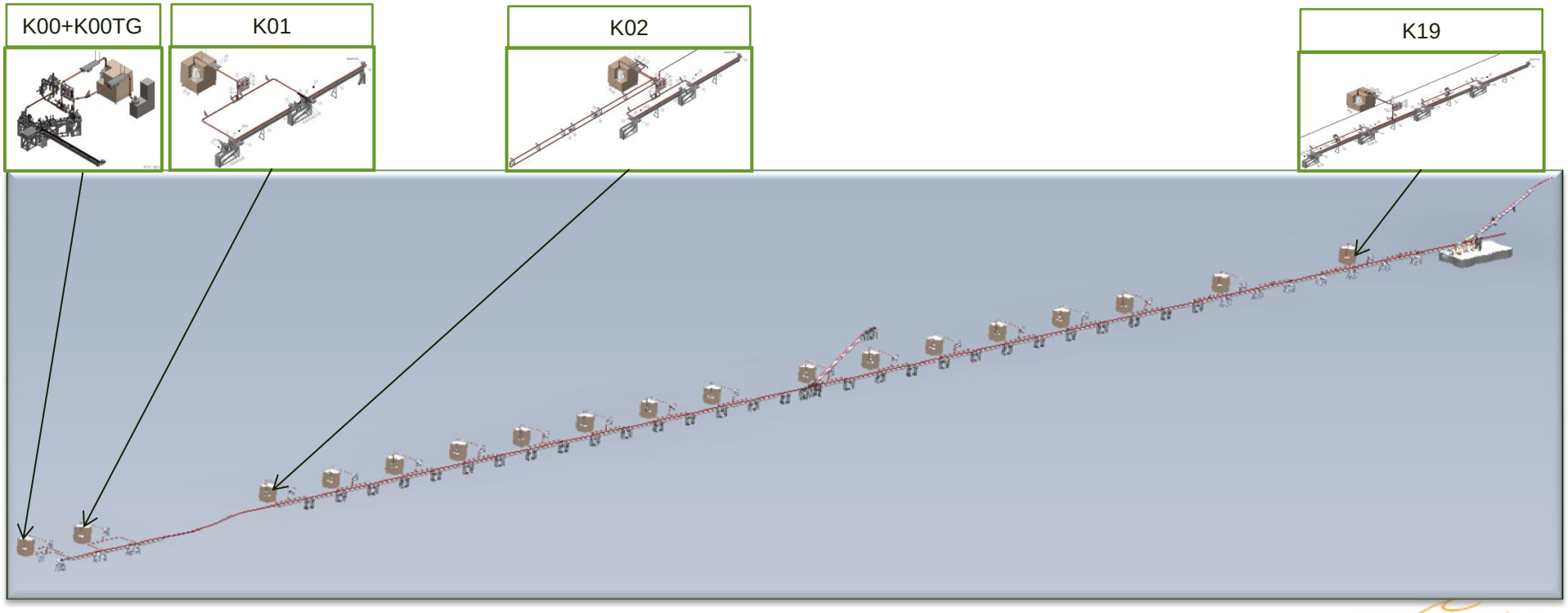
The linac should be used as an injector for both the 1.5 and 3 GeV storage rings and the SPF (Short Pulse Facility)

- **18 klystrons**
- **18 SLEDS**
- **39 linac structures**
  - **Operating frequency 2998.5 MHz**
  - **Maximum rep. rate 100Hz**
  - **Maximum RF power 35 MW**
  - **RF pulse length 4.5µs**
  - **Linac length 250 m**
- **Two Electron sources**
  1. **One klystron (7.5MW) feeding a thermionic RF gun used for ring injections**
  2. **A photo cathode gun for the SPF fed from the first linac klystron**

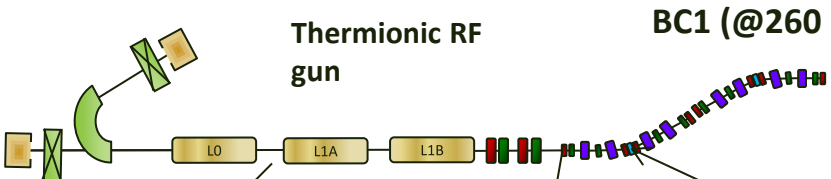
Operating beam energy 3 GeV
Max. on-crest beam energy 3.6 GeV
➡ **44% RF power redundancy**

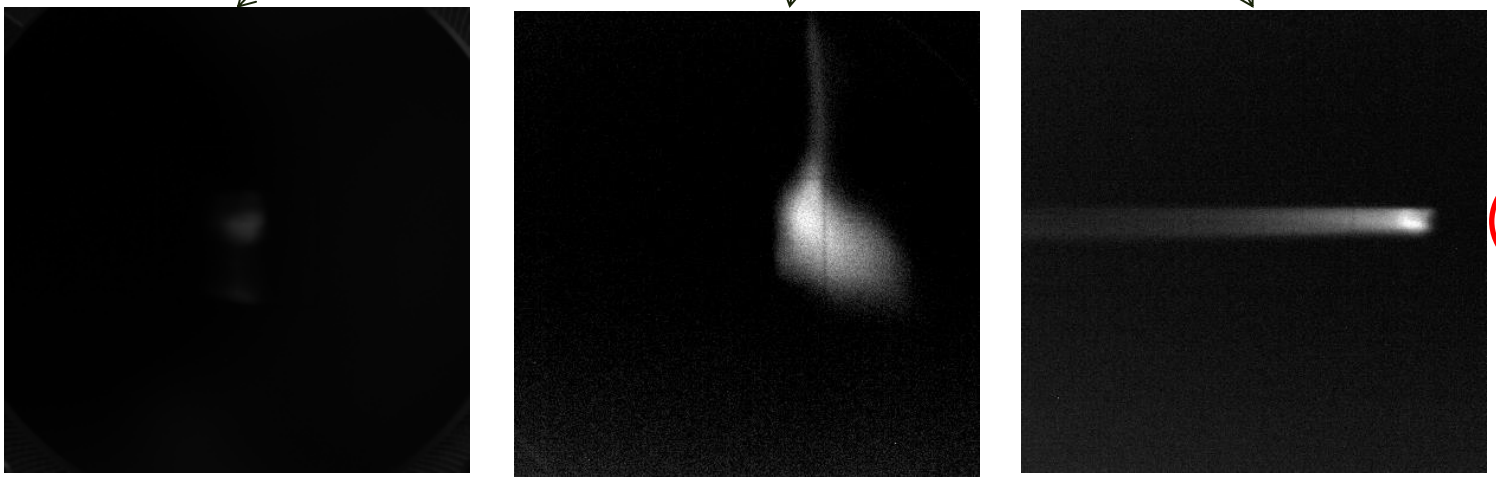
MAX IV linac

- RF conditioning take longer time than anticipated despite that everything except the waveguides is preconditioned by RI. Problems with the subsystems have limited the time for conditioning
- The first three RF stations are fully conditioned
- The personal safety system PSS has been changed so that it is possible to accelerate electrons up to the first bunch compressor while RF conditioning can continue in the rest of the linac
- Only minor impact on the Linac commissioning time schedule
- **The remedy** is baking all waveguides



Commissioning





Beam energy 280 MeV

Courtesy of Sara Thorin

MAX IV LABORATORY

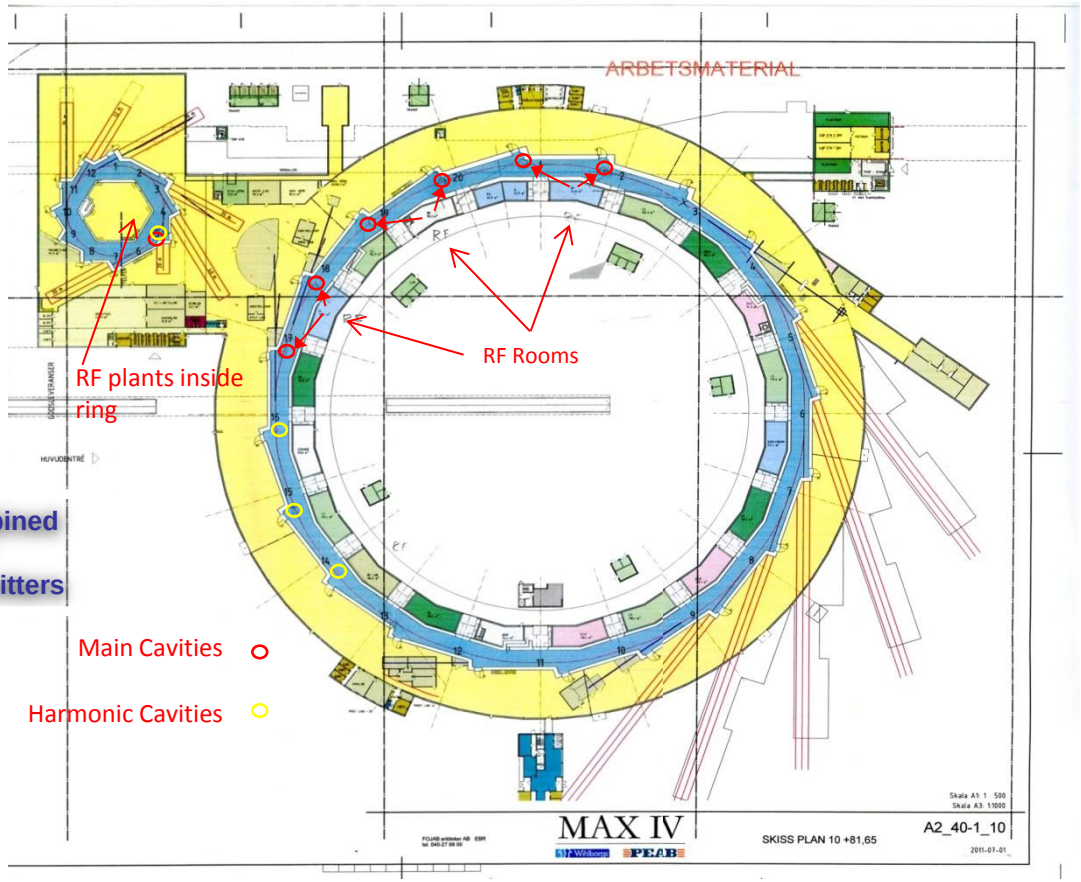
MAXIV Ring RF Systems

Storage Rings Parameters

Energy	1.5 GeV	3.0 GeV
RF	99.931 MHz	99.931 MHz
Circumference	96 m	528 m
Harmonic number	32	176
Current	500 mA	500 mA
No of cavities	2	6
RF station power	60kW	120kW
Cavity voltage	280kV	300kV
Coupling (beta)	2.3	4.0

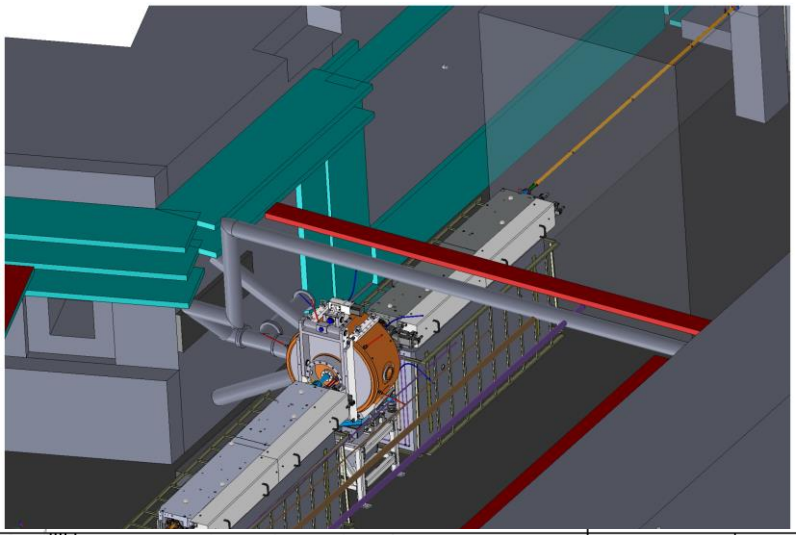
2 combined 60 kW transmitters

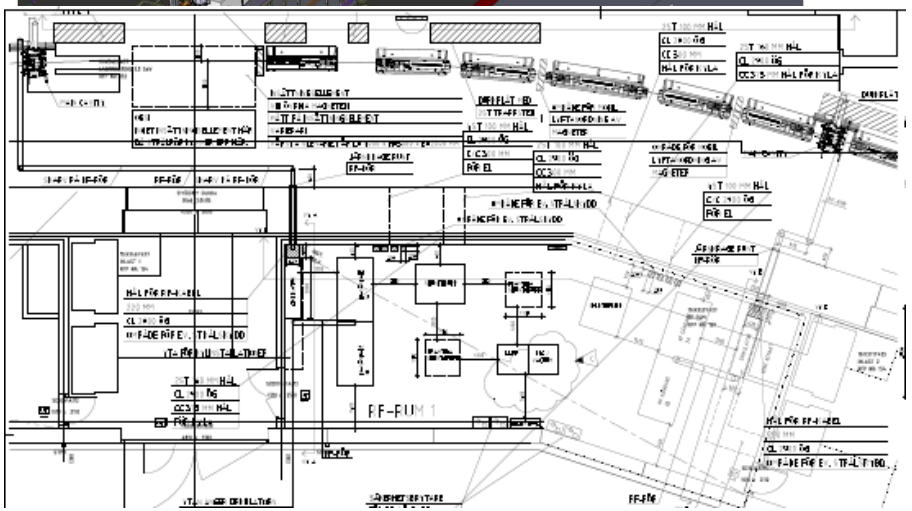
1 single 60 kW transmitters



Ring RF Systems - 3 GeV Ring RF

- The main cavities are placed in the second short straight section of six consecutive achromats.
- Each RF-room contains two RF power plants.

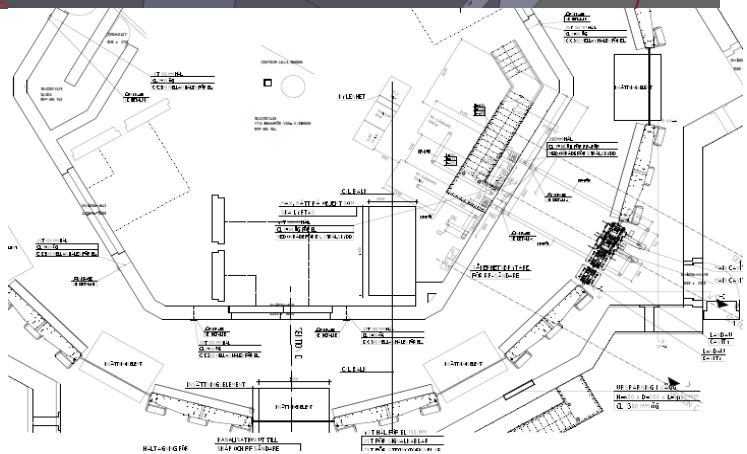




3 GeV ring mock-up

Ring RF Systems - 1.5 GeV Ring RF

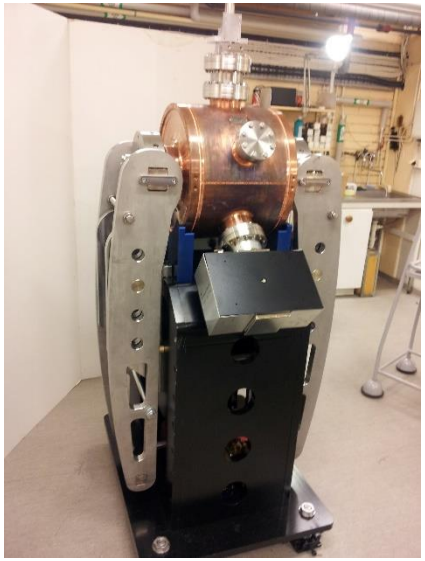
- Two Main Cavities and two Harmonic Cavities occupy one straight section
- Two 60 kW Power Plants are placed inside the ring.



RF Systems - Cavities

- Cavities (100 and 300 MHz)
- All main cavities including two for Solaris Poland
  - **Delivered October - December 2013**
- Conditioning ongoing at Maxlab
- Production of water cooling stations ongoing
- Tuning system for Harmonic cavities (HC): **Delivered November 2013**
- First two HC cavities: **Delivered September 2014** (Solaris)
- 300 MHz Power source for conditioning of HC ready

300 MHz power source for conditioning of harmonic (Landau) cavities



-Power demand min. 5kW
-Will be used only for conditioning of 7 cavities.
Shouldn't be too expensive.
-High power 300MHz amplifier not easy to find (expensive)
-Possible solution is….

-Old VHF 10kW TV transmitter

-Max. frequency 224MHz, not possible to "squeeze" output cavity any more

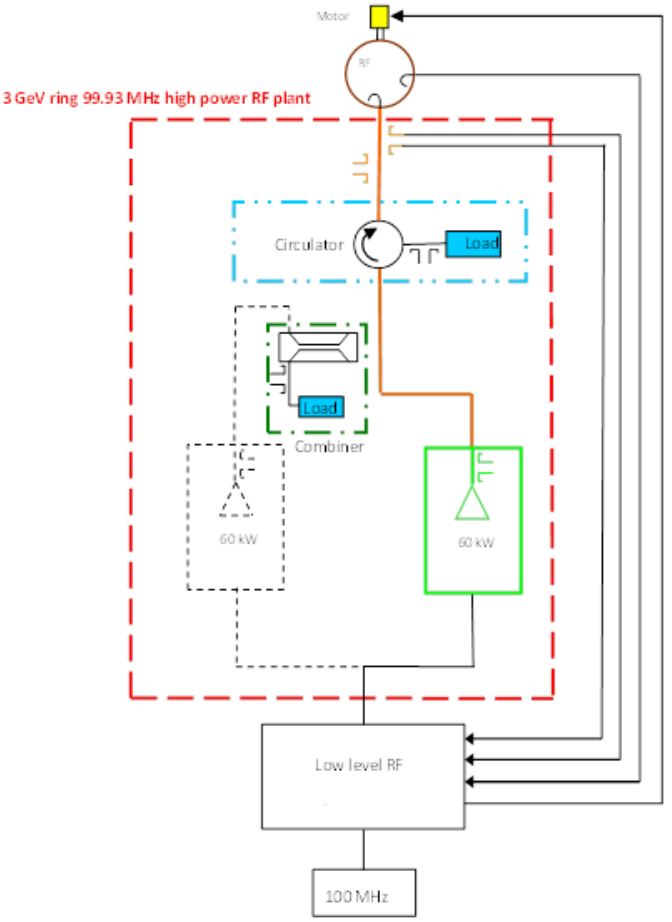
-Solution…

300 MHz power source for conditioning of harmonic (Landau) cavities

-Design of new cavity
-Original cavity is TE11 mode cylindrical cavity
-New is TEM mode coaxial cavity +1/2 λ
-Simple formulas used
-Calculations confirmed by simulation in Comsol and prototype

Ring RF Systems – High Power Plants

- Contracts signed for
  - High power amplifiers (Electrosys, Italy). The delivery time was delayed because of severe financial problems in the company. The risk was too large to continue so the contract was canceled (June 2014). **A new contract has been signed** (September 2014)for delivery of 60 kW liquid cooled solid state power amplifiers (Rohde & Schwarz, Germany)
  - Circulators (AFT, Germany)
  - Transmission Lines and Integration Work (Exir Boadcasting AB, Sweden)
- **Delivery of high power amplifiers: December 2014 two for test of circulators, two in February 2015 , two in March and finally two in June 2015 (1.5 GeV)**



Ring RF Systems – High Power Plants

- Rohde & Schwartz 60 kW CW solid state liquid cooled amplifiers based on two 30 kW transmitters/amplifiers with additional power combiner
- >64% overall power efficiency
- High MTBF
- Compact: 2000 mm × 600 mm × 1100 mm (HxWxD)
- Coolant: glycol/water

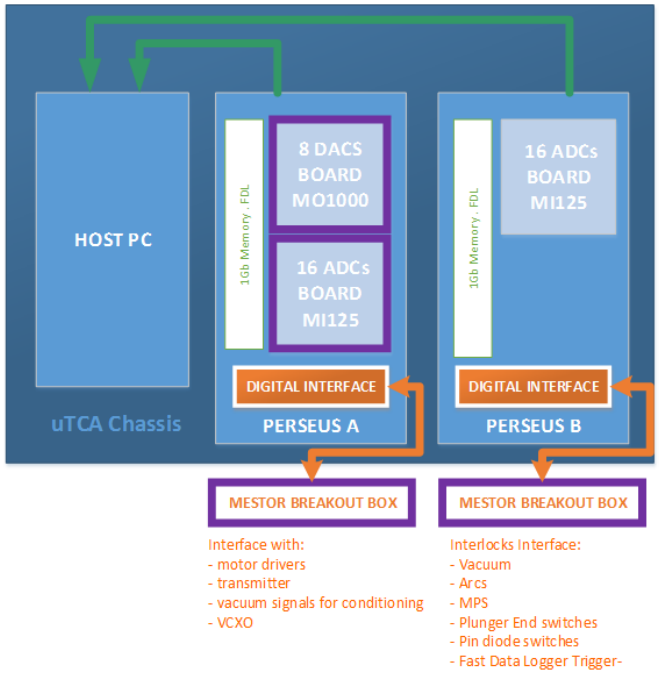
One pump unit and heat exchanger per rack

Digital Low Level RF

Design by Angela Solom
GUI by Antonio Milan

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

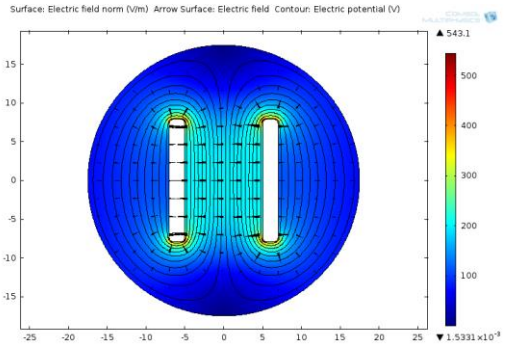
- The DLLRF is upgraded to a new more powerful FPGA platform, Perseus from Nutaq. High power tests has been performed in beginning of September 2014.
- This makes it possible to implement two independent loops besides the tuning loop. One for the cavity field and one for the phase of the forward power
- Production of all front ends for the digital LLRF systems are ongoing.



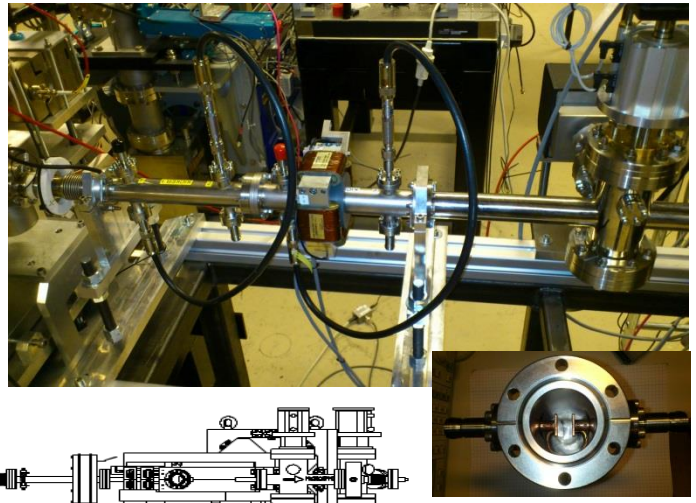
Chopper for Ring Injection

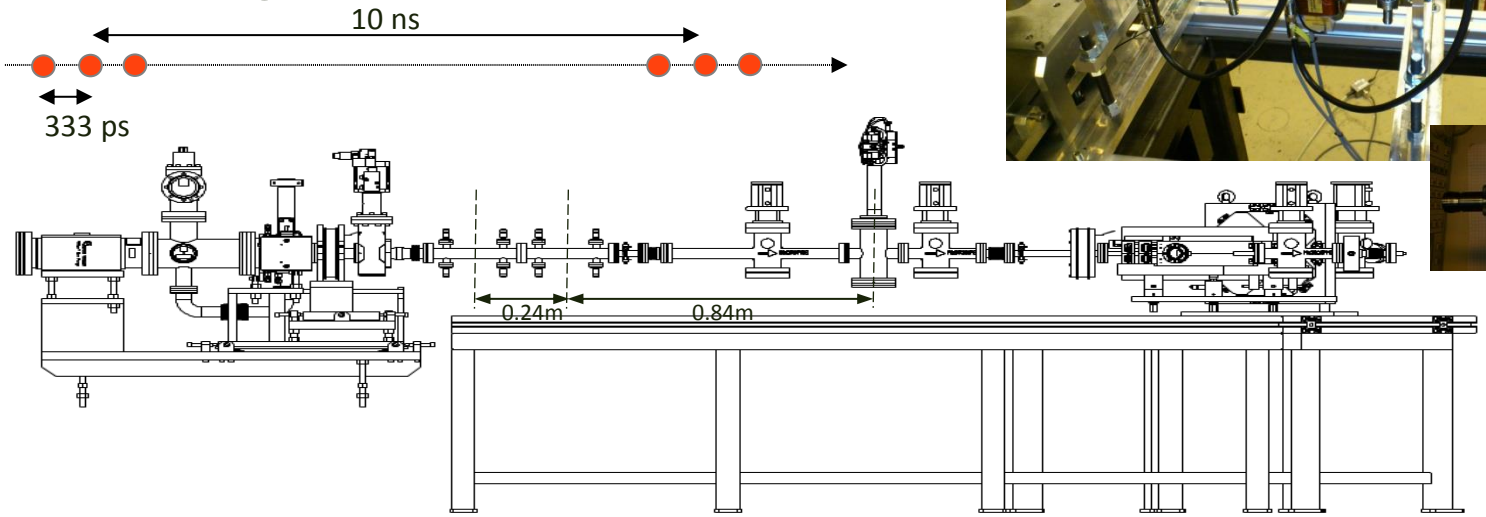
- Has two identical vertical kickers.
- The kickers consist of a 15 cm long stripline pair with a characteristic impedance of 50 Ω for odd TEM modes.
- Both electrodes are fed by RF
- An aperture is located downstream. The unwanted bunches will be dumped here.
- The aperture can be selected so the wanted bunches either passes a 1 mm iris, a 2 mm iris, or over an edge.

2 D design

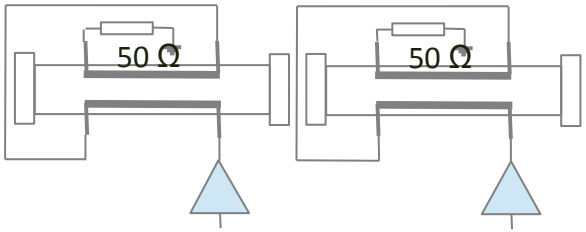


If $\phi_1=-\phi_2 \rightarrow$ Zo=49.9Ω
If $\phi_1= 0 \rightarrow$ Zo=63.8Ω
If $\phi_1= \phi_2 \rightarrow$ Zo=88.2Ω



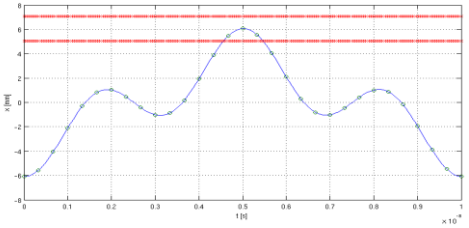


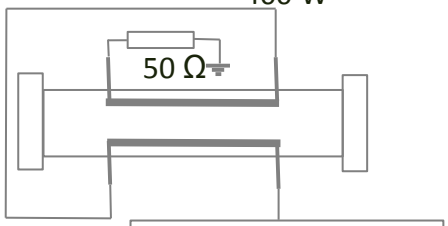
Kicker system for ring injection



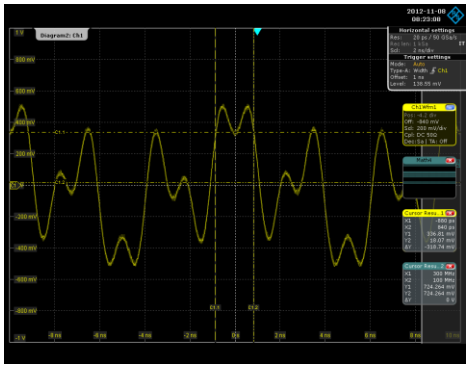
300 MHz
~400 W

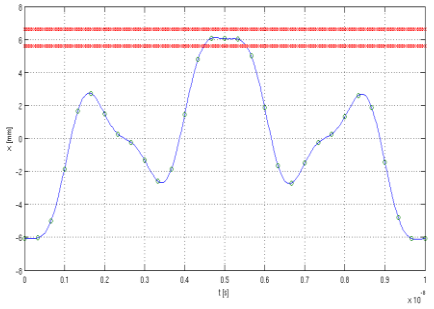
100 MHz
~1 kW





Combining network



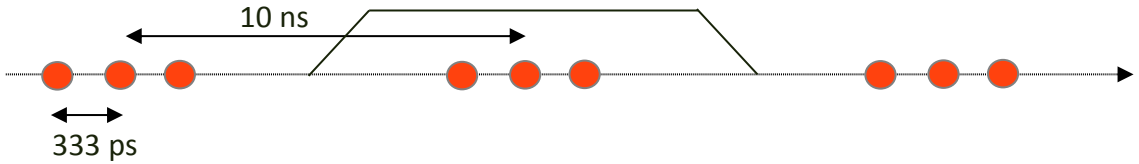


Crosstalk <-31db

100 MHz
~400 W

300 MHz
~1 kW

700 MHz
~300 W



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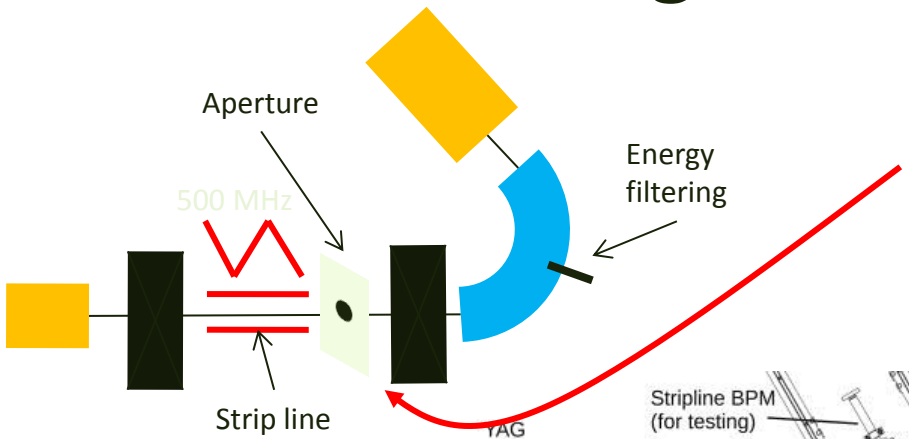
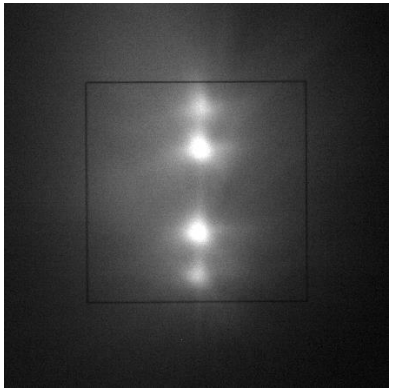
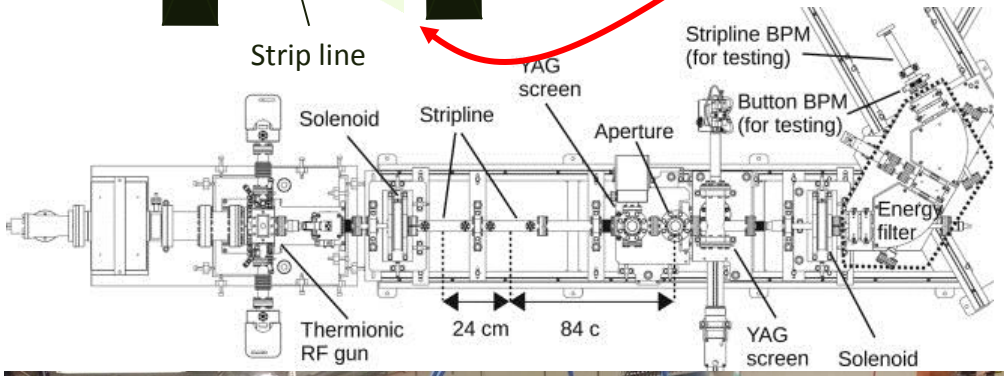
Thermionic gun commissioning

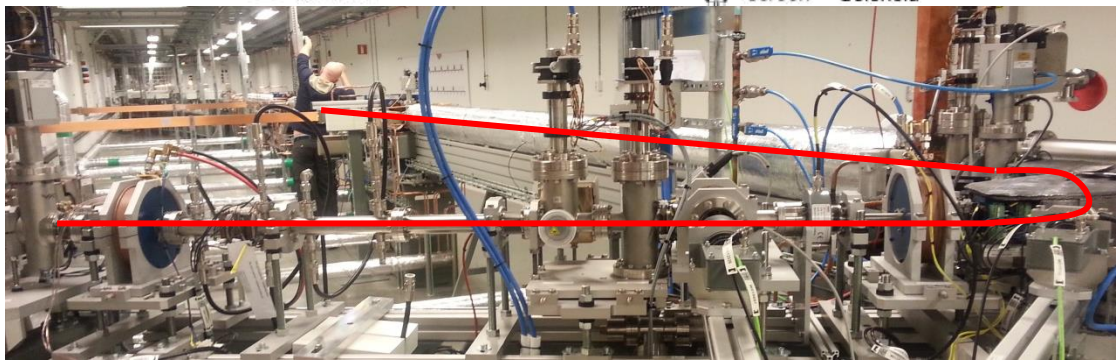


No aperture



With aperture





Commissioning parameters	
Charge	0.75 nC/shot
Rep rate	2 Hz
Chopper f	500 MHz

Courtesy of Sara Thorin

Thanks for your attention
Questions?