RF systems for the MAX IV rings

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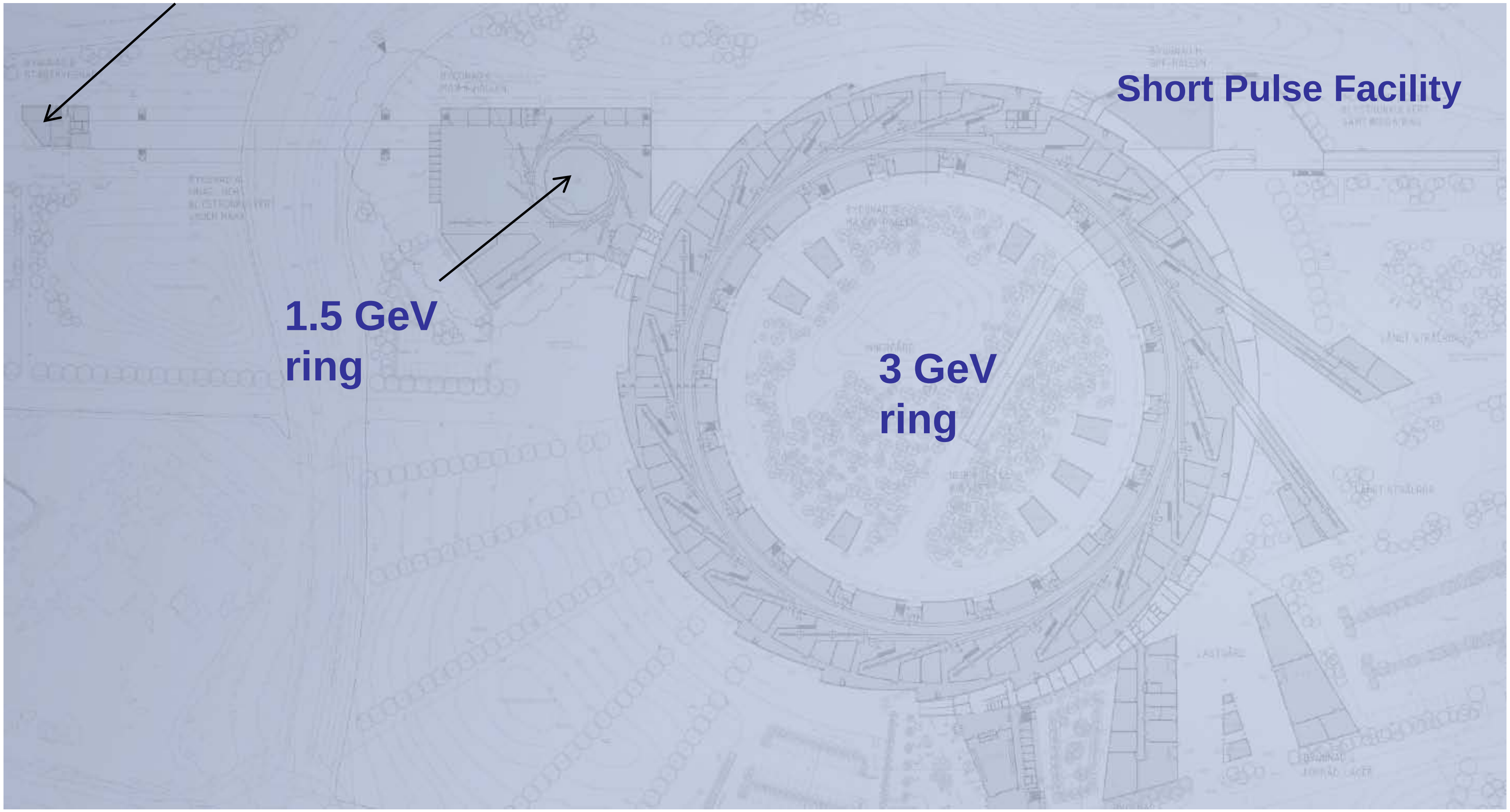
On behalf of the MAX-lab RF team

Outline

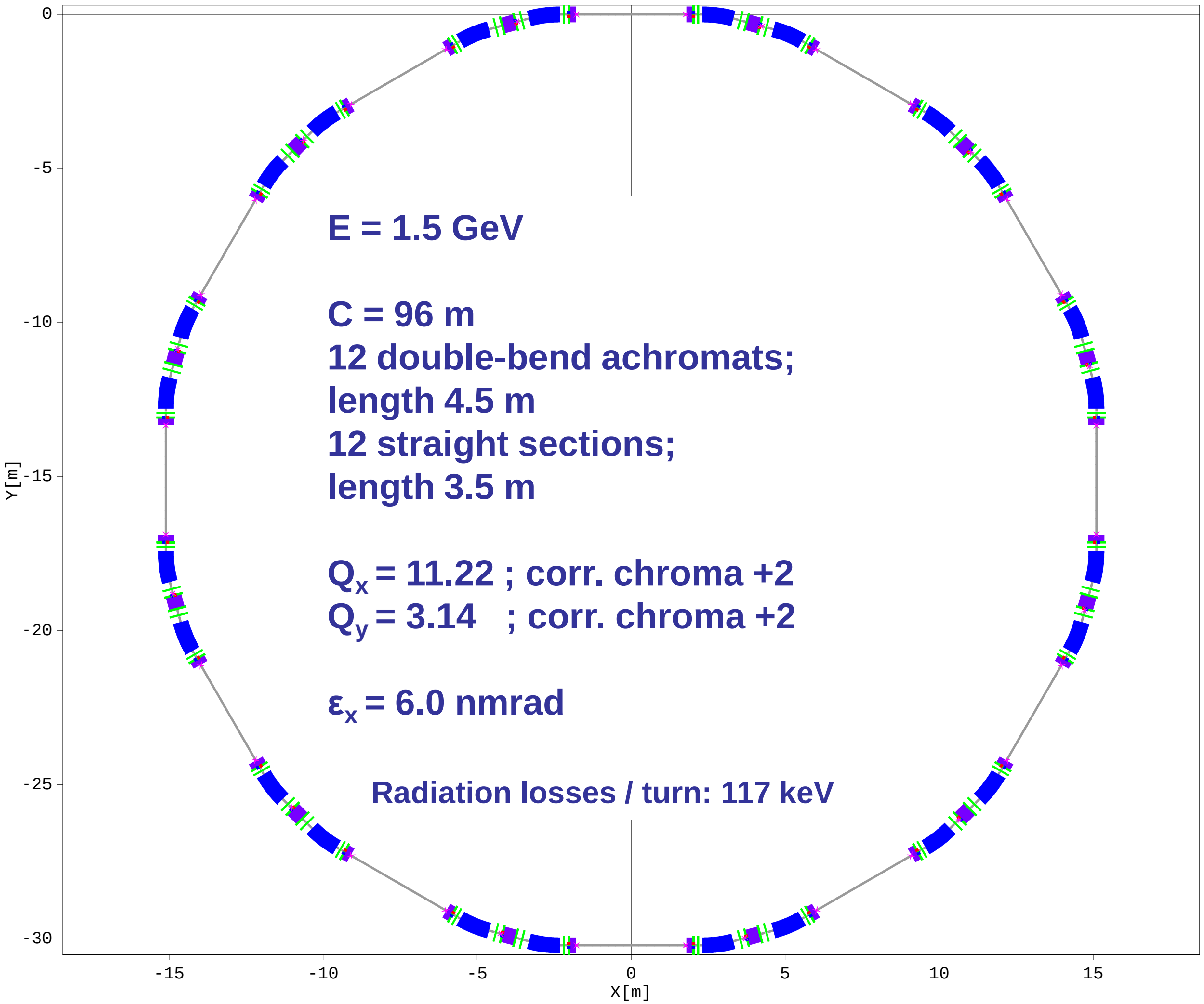
- MAX IV overview
- Ring RF overview
- Main cavity design
- Higher harmonic cavity design

MAX IV overview; site

Start 3.5 GeV Linac



MAX IV overview; 1.5 GeV ring



E = 1.5 GeV

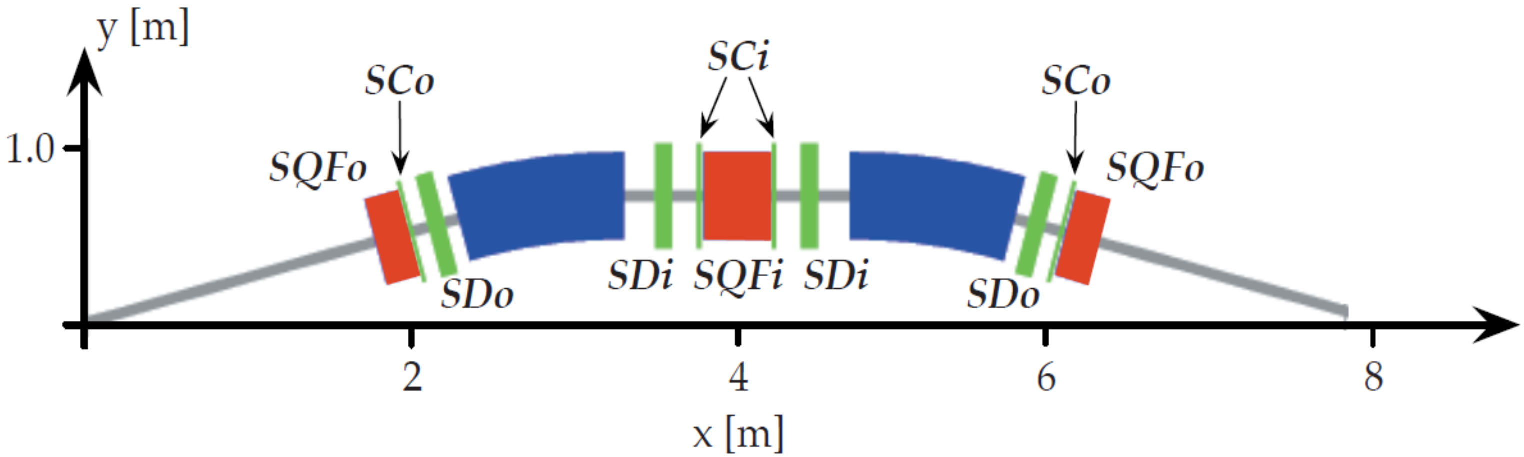
C = 96 m
12 double-bend achromats; length 4.5 m
12 straight sections; length 3.5 m

Q_x = 11.22 ; corr. chroma +2
Q_y = 3.14 ; corr. chroma +2

ε_x = 6.0 nmrad

Radiation losses / turn: 117 keV

MAX IV overview; 1.5 GeV ring

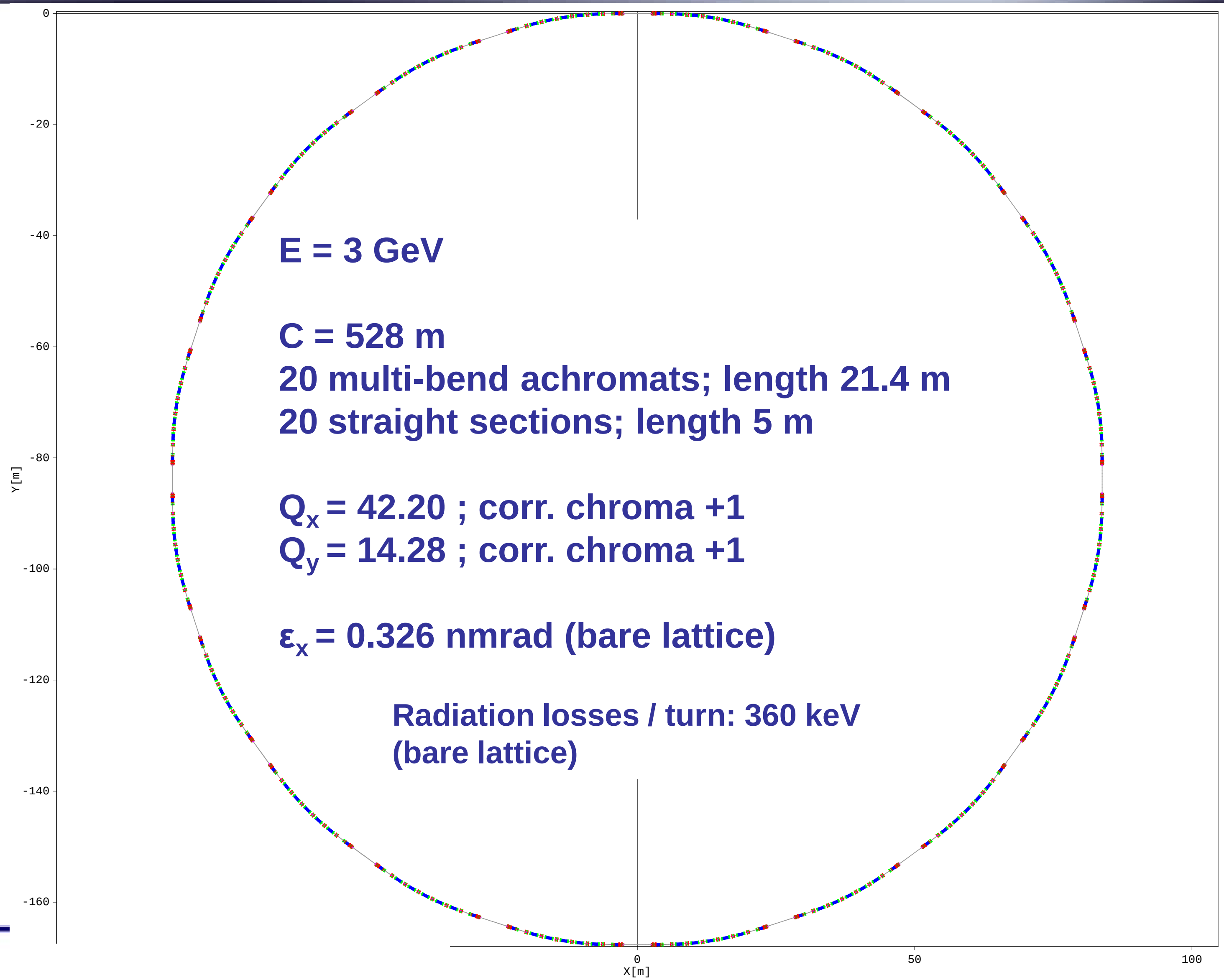


MAX IV overview; 1.5 GeV ring

Table 3.1: Parameters for the MAX IV 1.5 GeV storage ring.

Energy [GeV]	1.5
Main radio frequency [MHz]	99.931
Harmonic number	32
Circulating current [mA]	500
Circumference [m]	96
Number of achromats	12
Length of straight sections (BPM to BPM) [m]	3.5
Betatron tunes (horizontal / vertical)	11.22 / 3.14
Natural chromaticities (horizontal / vertical)	−22.9 / −17.1
Corrected chromaticities (horizontal / vertical)	+2.0 / +2.0
Momentum compaction factor	3.04×10^{-3}
Horizontal emittance (bare lattice) [nm rad]	6.00
Radiation losses per turn (bare lattice) [keV]	117.2
Natural energy spread (bare lattice)	0.75×10^{-3}
Required dynamic acceptance [mm mrad] (horizontal / vertical)	17.7 / 5.6
Required lattice momentum acceptance	±3.0%

MAX IV overview; 3 GeV Storage Ring



E = 3 GeV

C = 528 m
20 multi-bend achromats; length 21.4 m
20 straight sections; length 5 m

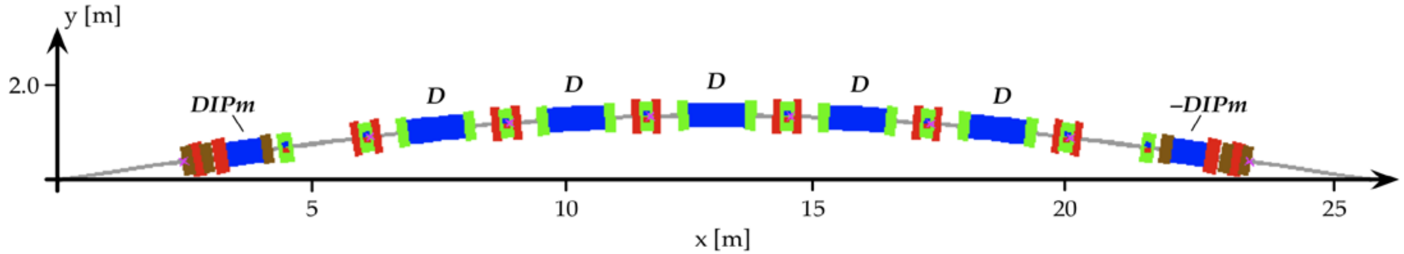
Q_x = 42.20 ; corr. chroma +1
Q_y = 14.28 ; corr. chroma +1

ε_x = 0.326 nmrad (bare lattice)

Radiation losses / turn: 360 keV (bare lattice)

MAX IV overview; 3 GeV ring

One of the 20 achromats in the 3 GeV ring



• Relatively compact magnet structure, except for two ”matching” short straights.

MAX IV overview; 3 GeV ring

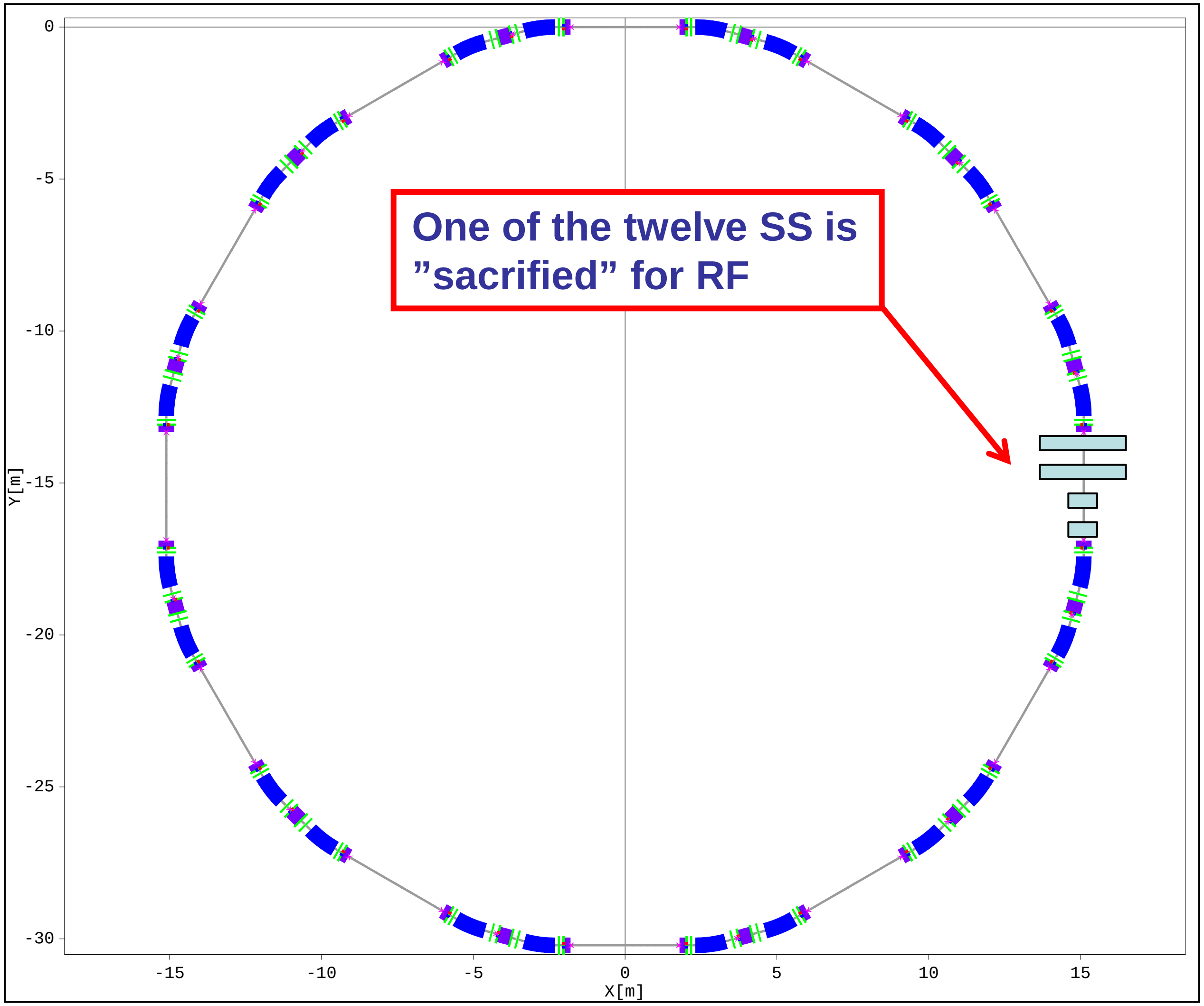
The Multi-Bend Achromat gives hor. emittance in the Intra Beam Scattering regime:

Main radio frequency [MHz]	99.931
Harmonic number	176
Circulating current [mA]	500
Circumference [m]	528
Horizontal emittance (bare lattice) [nm rad]	0.37 [0.326]
Horizontal emittance (with 4 d w and 10 in-vac. Und.) [nm rad]	0.23 [0.201]
Radiation losses per turn (bare lattice) [keV]	360
Radiation losses per turn (with 4 d w and 10 in-vac. Und.) [keV]	854
Natural energy spread (bare lattice) [%]	0.084 [0.077]
Natural energy spread (with 4 d w and 10 in-vac. Und.) [%]	0.094 [0.091]
Momentum compaction factor	3.0 x 10e-4
Required lattice momentum acceptance	± 4.5 %
Rms bunch length with Landau cavities [mm]	50
Vertical emittance [pm rad]	8

[ ] = without IBS

➔ Landau cavities are essential in order to reach the design horizontal emittance!

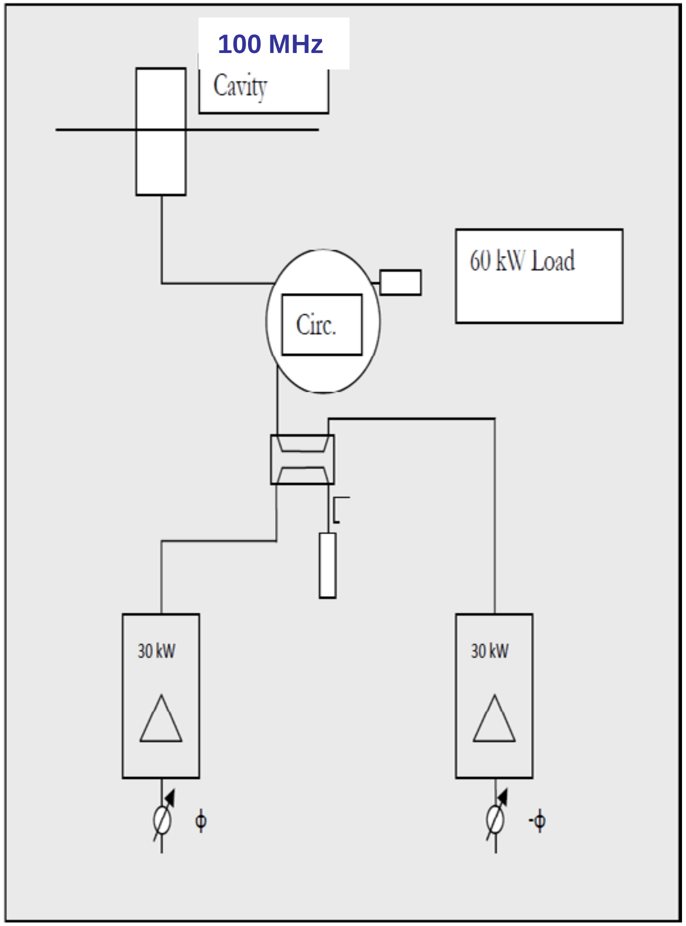
Ring RF overview; 1.5 GeV



Ring RF overview, 1.5 GeV ring

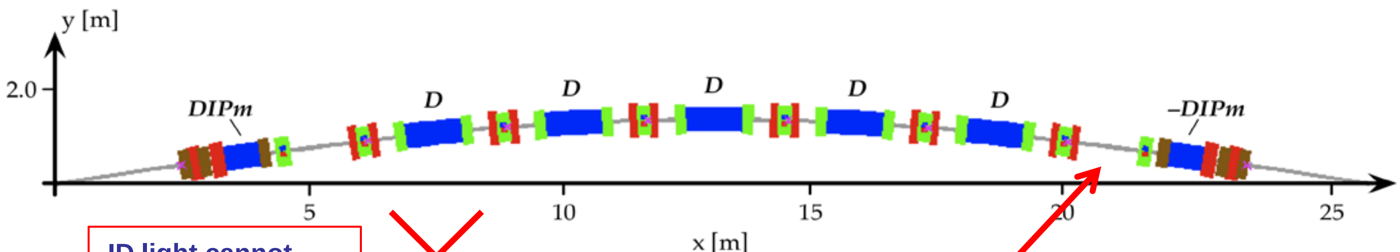
	Lund	Krakow
Case	I	II
Energy loss with Ids	130keV	150keV
Circulating current	0.5A	0.5A
Total beam power	65kW	75kW
Total RF voltage	0.56MV	0.5MV
Number of cavities	2	2
Cavity shunt impedance	3.2Mohm	3.2Mohm
Cu losses	49kW	39kW
Total RF power needed	114kW	114kW
Nr of RF stations	2	2
Nr of transmitters	4	4
Transmitter power	28.5kW	28.5kW
Power to cavity	57kW	57kW
Cu losses/cav	24.5kW	19.5kW
Coupling (beta)	2.3	2.9
Cavity voltage	280kV	250kV
Bucket height	4.0%	3.5%

Table 1: Two anticipated RF scenarios for the 1.5 GeV ring.



Ring RF overview; 3 GeV ring

One of the 20 achromats in the 3 GeV ring

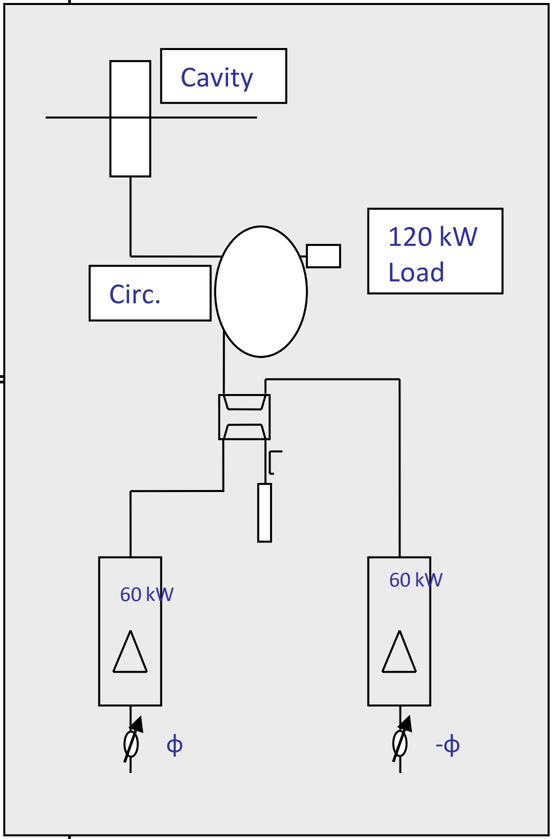


ID light cannot pass the cavity

None of the twenty SS is "sacrified" for RF. Instead we will use nine short matching straights upstream the SS.

Ring RF overview; 3 GeV

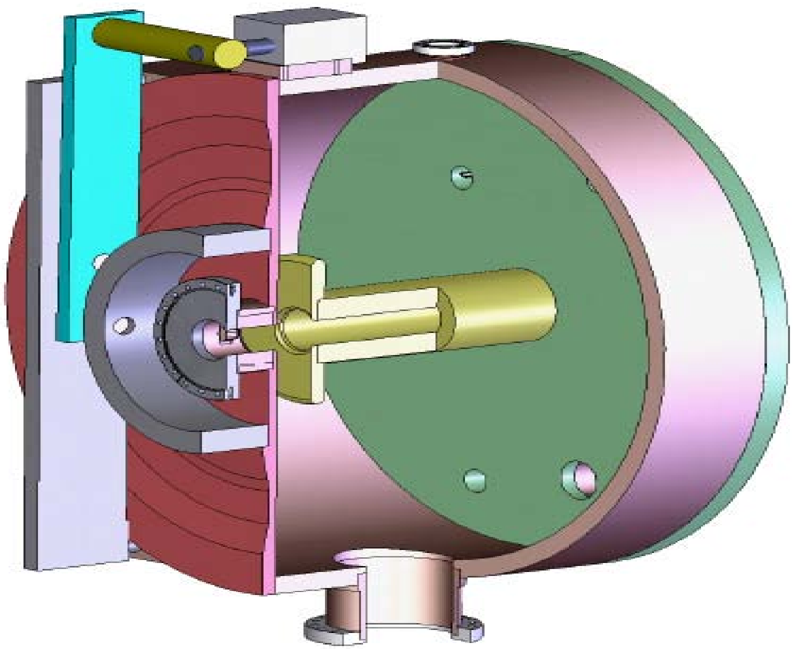
Alternative	I	II
Energy loss with Ids	756keV	1020keV
Circulating current	0.5A	0.5A
Total beam power	378kW	510kW
Total RF voltage	1.5MV	1.8MV
Number of cavities	6	6
Cavity shunt impedance	3.2Mohm	3.2Mohm
Cu losses	117kW	169kW
Total RF power needed	495kW	679kW
Nr of RF stations	6	6
Nr of transmitters	12	12
Transmitter power	41.5kW	56kW
Power to cavity	83kW	113kW
Cu losses/cav	20kW	28kW
Coupling (beta)	4.2	4.0
Cavity voltage	250kV	300kV
Cavity gap	4cm	5cm
Bucket height	4.5 %	4.5 %

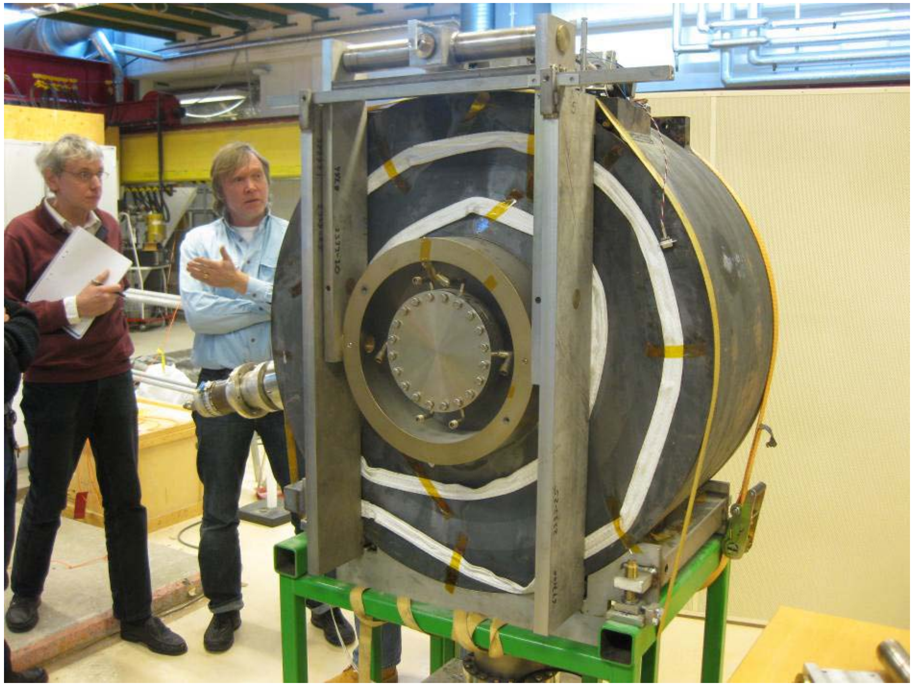


Alt I: Represents a solution for a 60% ID equipped ring, with the present MAX II/ MAX III cavities.
Alt II: Represents a solution for a fully ID equipped ring, with slightly modified MAX II/MAX III cavities.

Main cavity design

- **MAX II & MAX III main cavity**

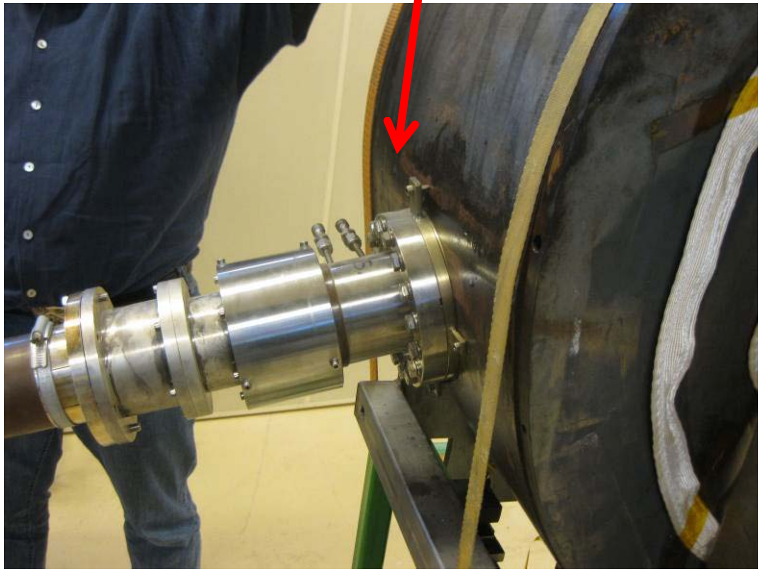


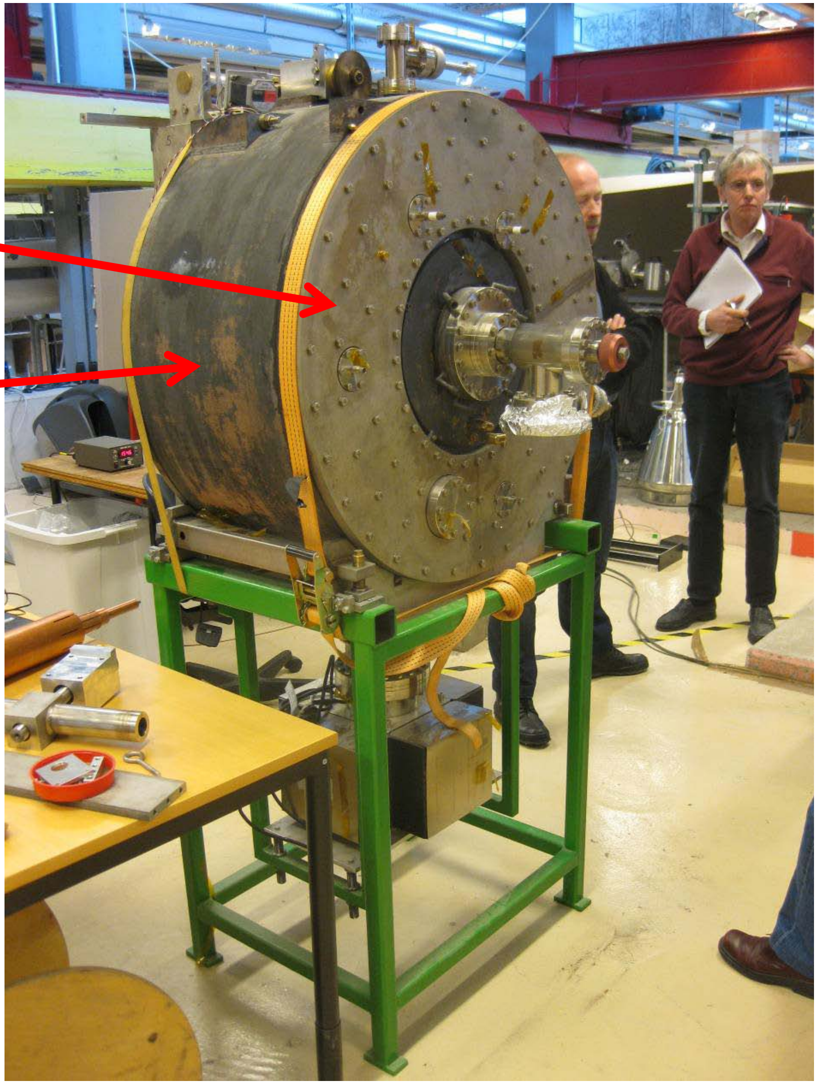


Mechanical design:
Leif Thånell, MAX-lab (retired)

Main cavity design

- <u>What we need to do better!</u>
- Cu became too soft after soldering
- An ”in air” weld of the shell (Ø 82 cm) had leaks.
- Water cooling of the shell





Main cavity design

- **What we need to do better!**
- Cu became too soft after soldering
- An ”in air” weld of the shell (Ø 82 cm) had leaks.

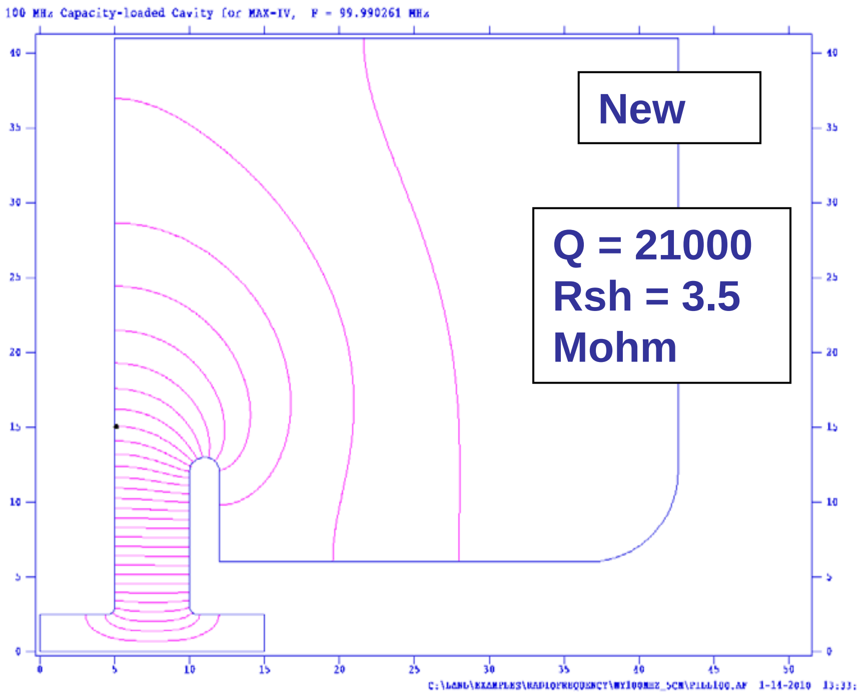
Electron Beam Welding seems to be the solution, but we need to learn:

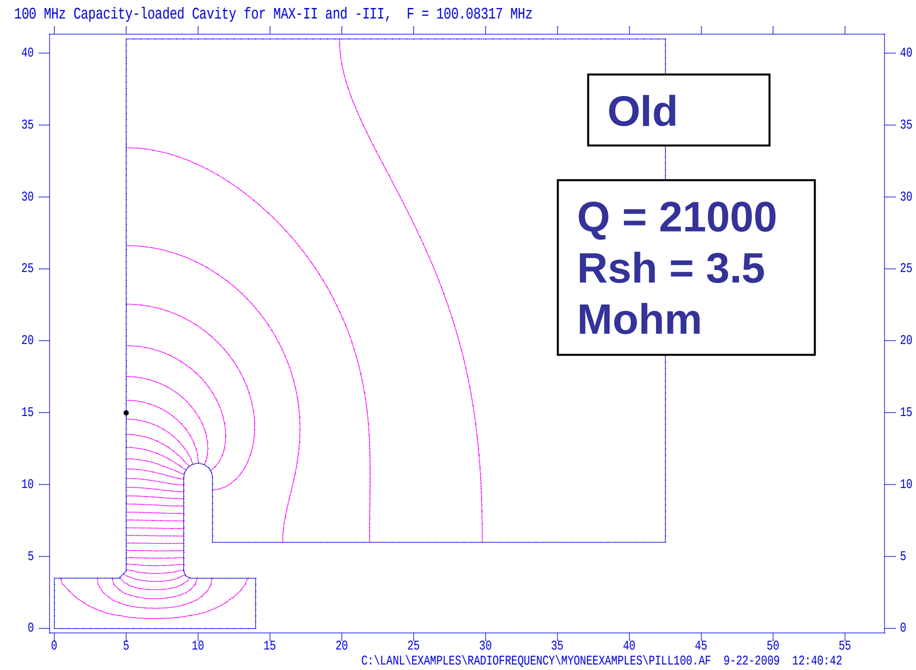
- How stiff OFHC copper can we excpect to get for the end plates, from industry?
- Rp0.2 of 180 MPa?
- How much does an EBW soften the material around the weld?
- Do we really need to stay in the elastic region when we tune the cavity?
- Can we safely construct the shell out of two half shells?

For the final weld:
What is the weld shrinkage?
Do we get a decent inner RF contact at the weld stop?

Main cavity design

Cavity profile modification for 250 kV → 300 kV





5 cm gap instead of 4 cm → slightly larger capacitor plate → We want to improve the cooling of the plate.

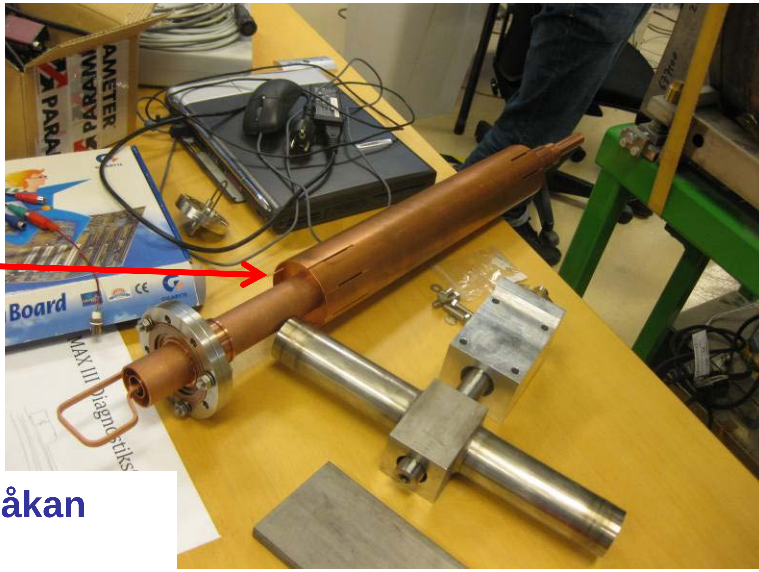
→ **Difficult to avoid water-to-vacuum joints! OK, or not?**

Main cavity design

- We are looking for a 120 kW input power coupler. Would the old DORIS coupler stand this power at 100 MHz?

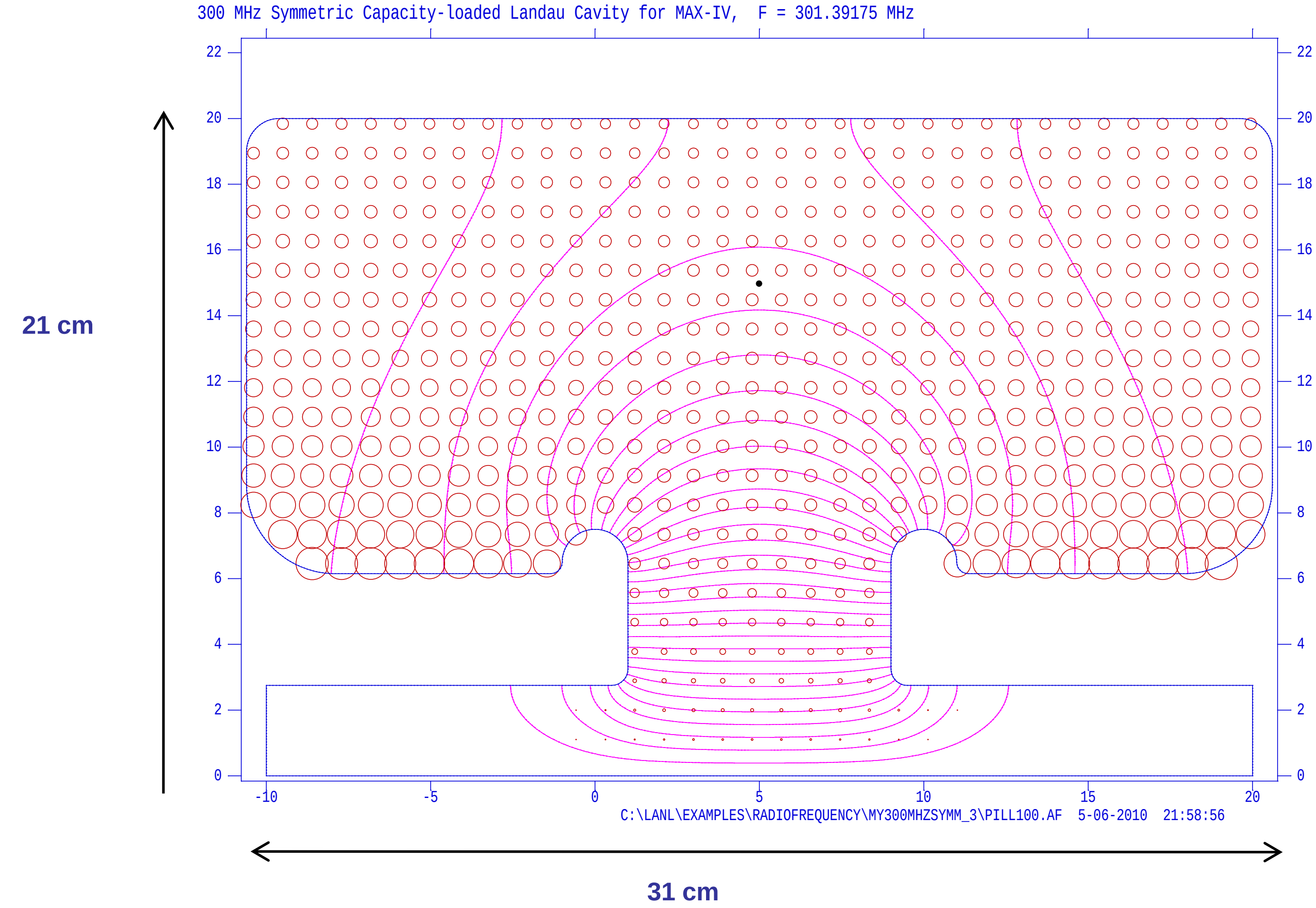
- We are (slowly) starting to look into HOM couplers. We put hope to the fact that the first dangerous HOM is at appr. 4.5 times the fundamental mode.

First prototype of a coaxial lambda/4 resonator rejection filter



Mechanical design: Håkan Svensson, MAX-lab

Landau cavity design

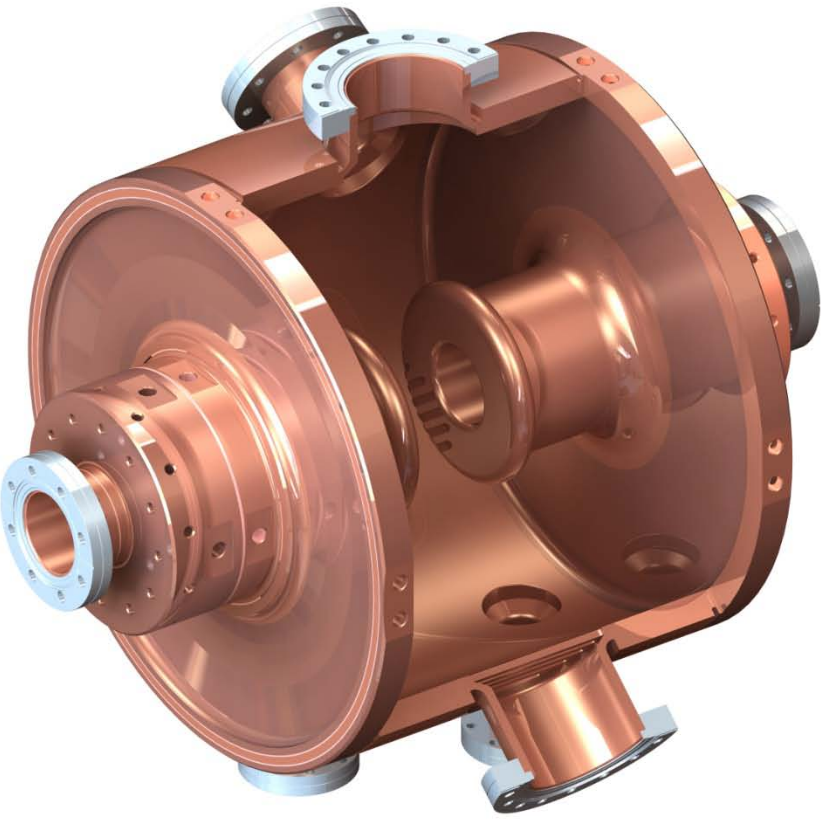


f = 300 MHz
Rsh = 5 Mohm
Q = 21600

We need three in the 3 GeV ring, and one – two in the 1.5 GeV ring

Landau cavity design

Prototype on its way!

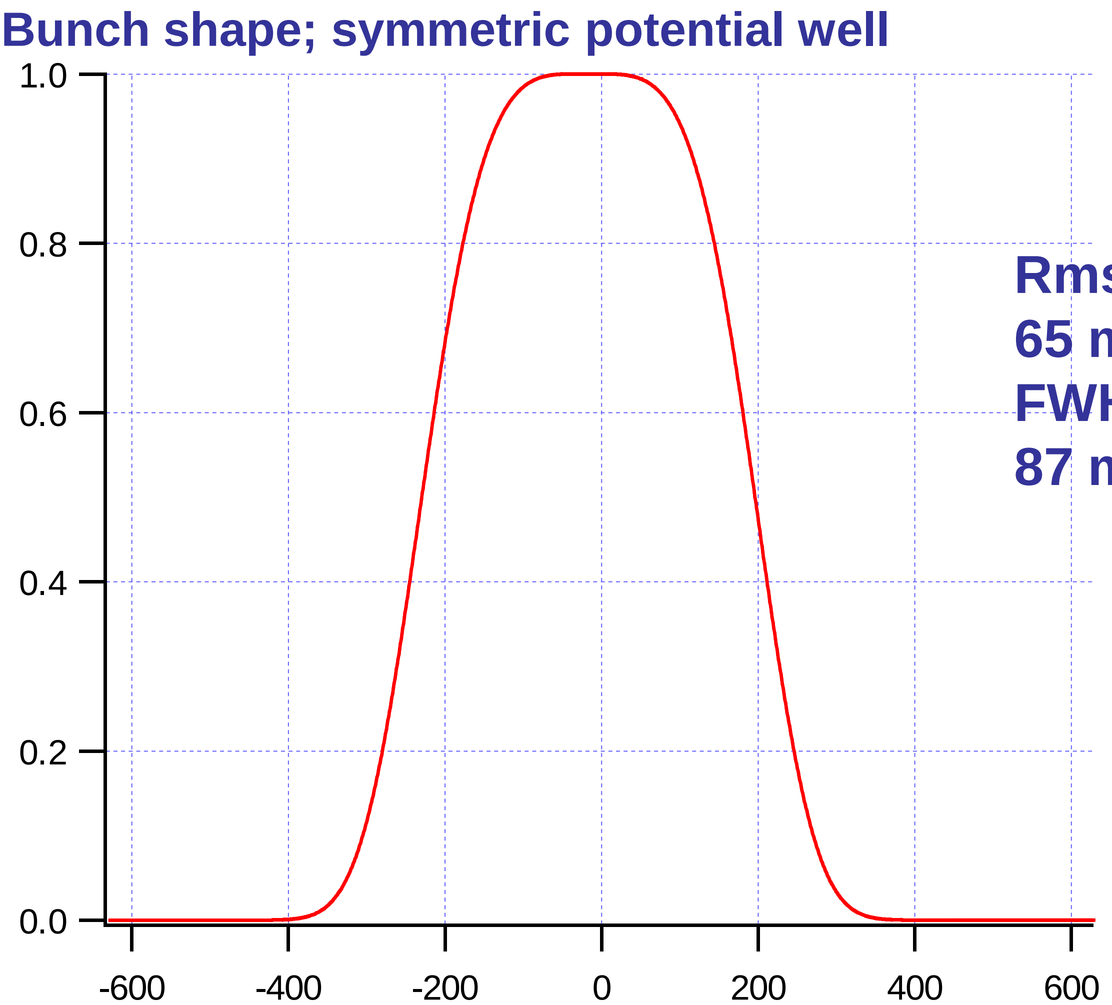


Mechanical design;

Elsayed Elafifi, MAX-lab

Extra slide, Landau cav. 1.5 GeV ring

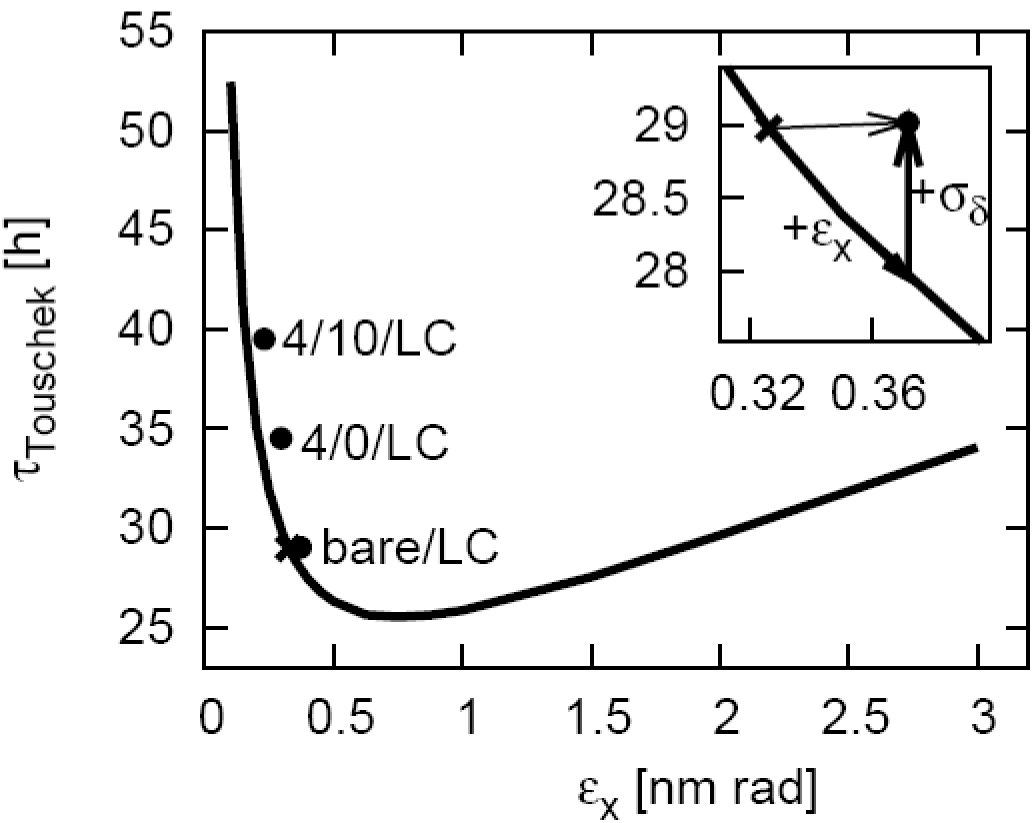
Calculated bunch shape with the double RF in the 1.5 GeV ring



Rms length: 65 mm
FWHM/2.35: 87 mm

We measure almost identical shapes in MAX-II in user operation.

Extra slide on Touschek lifetime, 3 GeV ring



δ_{acc} = 4.5 %
ε_y = 8 pmrad
σ_l = 50 mm