Further experience of the 100 MHz RF system and design of a new pre-injector

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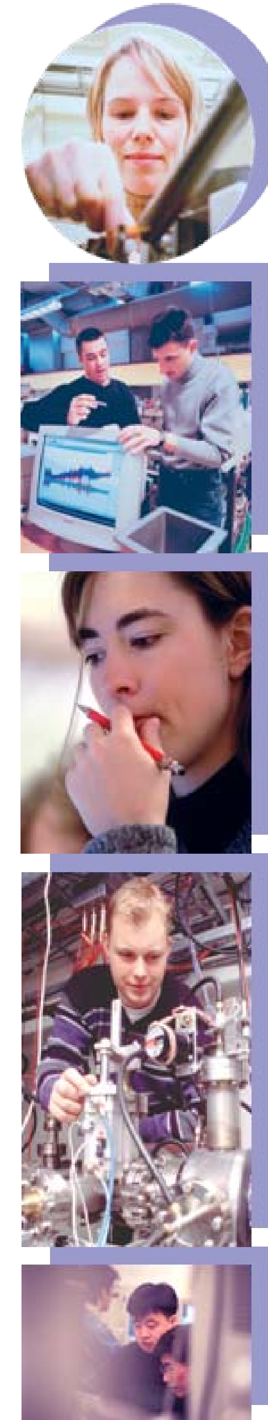
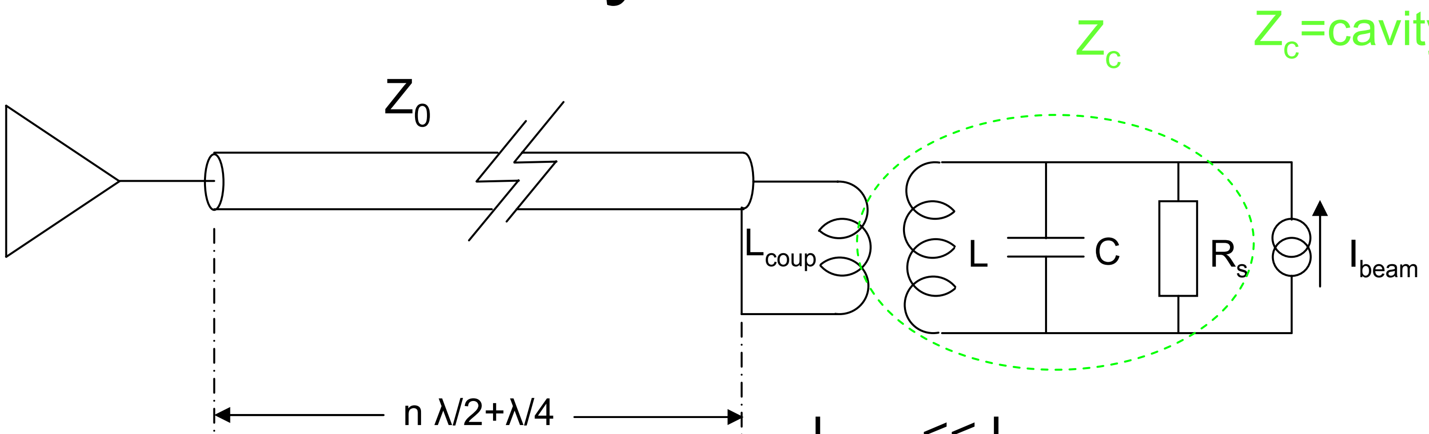


Facts and figures

	MAX-II
Frequency [MHz]	99.956
Harmonic number	30
No of cavity cells	3
No of transmitters	3
Cell radius [m]	0.41
Tot length of cavities [m]	1.5
Tot R_{shunt} ($\equiv$V*V/P) [MΩ]	9.6
Q-value	19000
Tot Voltage [kV]	450 (530)
Cu losses [kW]	21 (29)
Beam power @ 250mA [kW]	35 (50)
Available power [kW]	90
Net power [kW]	93(135)
Bucket height [%]	3.0
Synchrotron frequency [kHz]	8
Rms bunch length [cm]	1.7

Simple circuit model of the RF-system with beam

Z_c=cavity impedance



$L_{coup} << L$

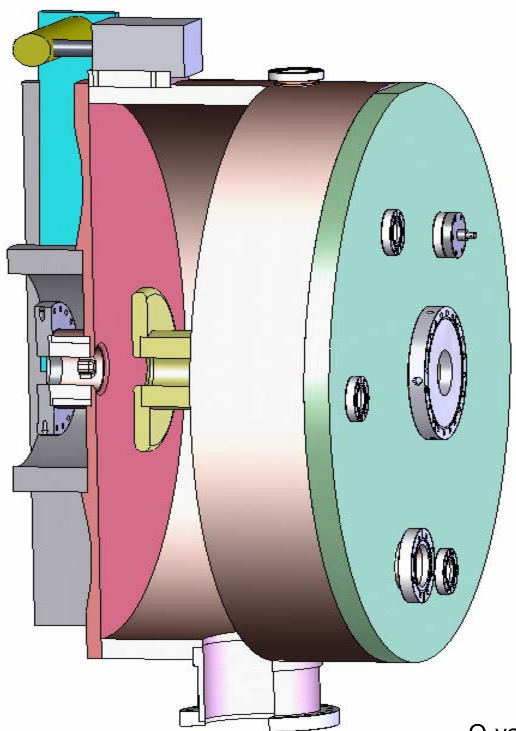
$$\beta = \frac{R_S}{Z_0} \cdot \frac{L_{coup}}{L}$$

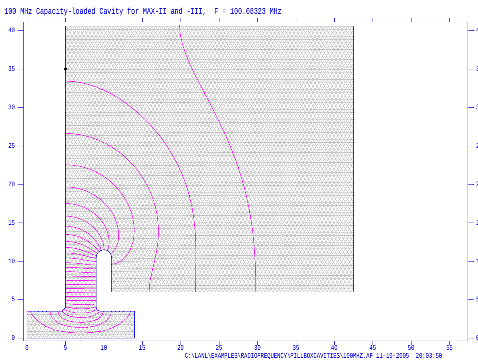
$$Z_0 = \frac{R_S}{\beta} \cdot \frac{L_{coup}}{L}$$

N^2

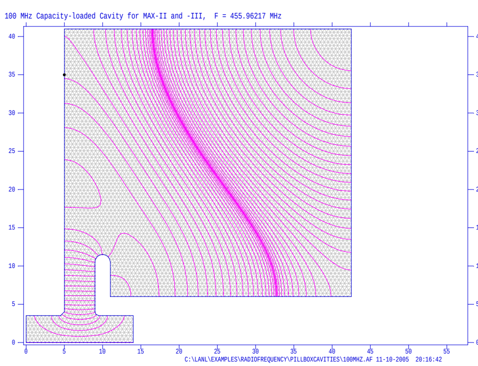
N=transformer ratio

100 MHz cavity





100 MHz cavity profile with fundamental mode E-field lines



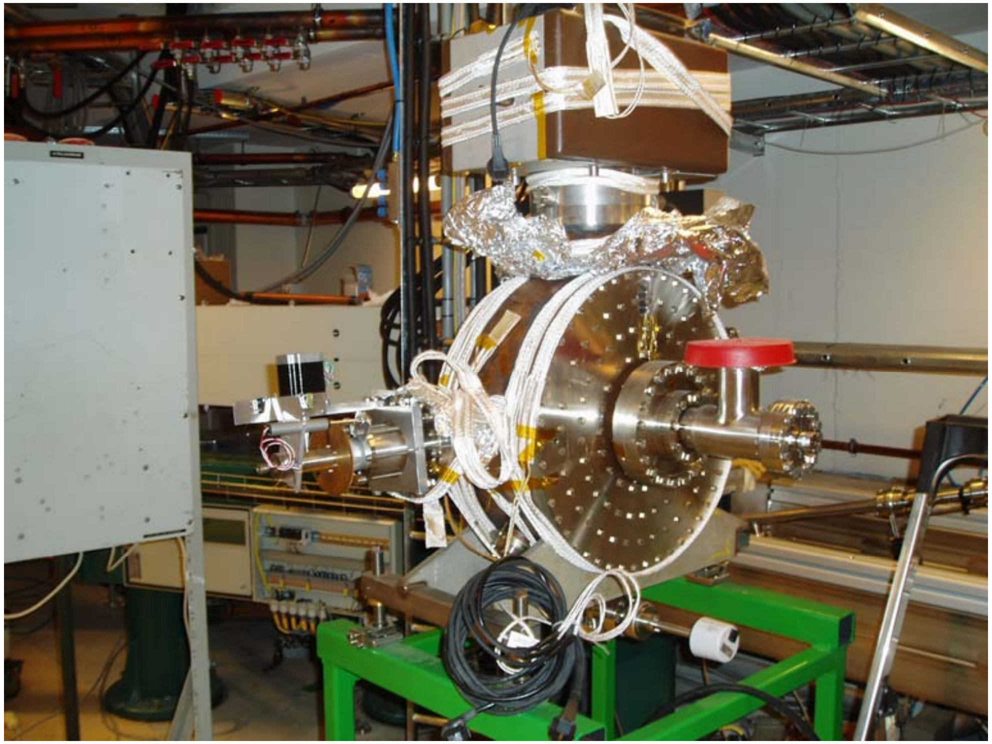
E-field lines of the high order mode at 456 MHz

Q-value 19000

Tot. R_{shunt} 3.2 MΩ

The high order modes are damped by antennas in the endplate. This endplate is convenient to use since the fundamental mode is not affected.

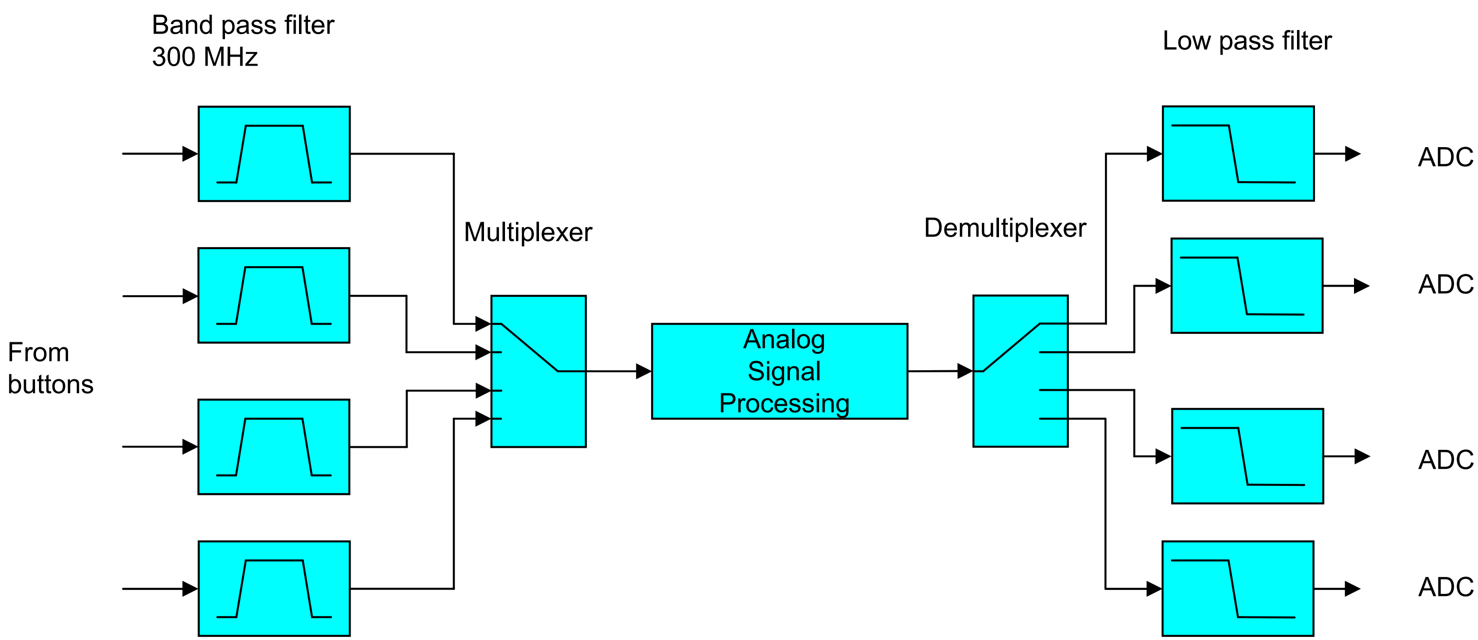
Landau cavity



Frequency [MHz]	499.780
No of cavities	1
Tot Rshunt (≡V*V/P) [MΩ]	3
Q-value	24000
Cu losses	
@ opt tuning [kW]	3.3

The Landau cavities are of simple pill-box type. Tuning is done both by plunger and temperature.

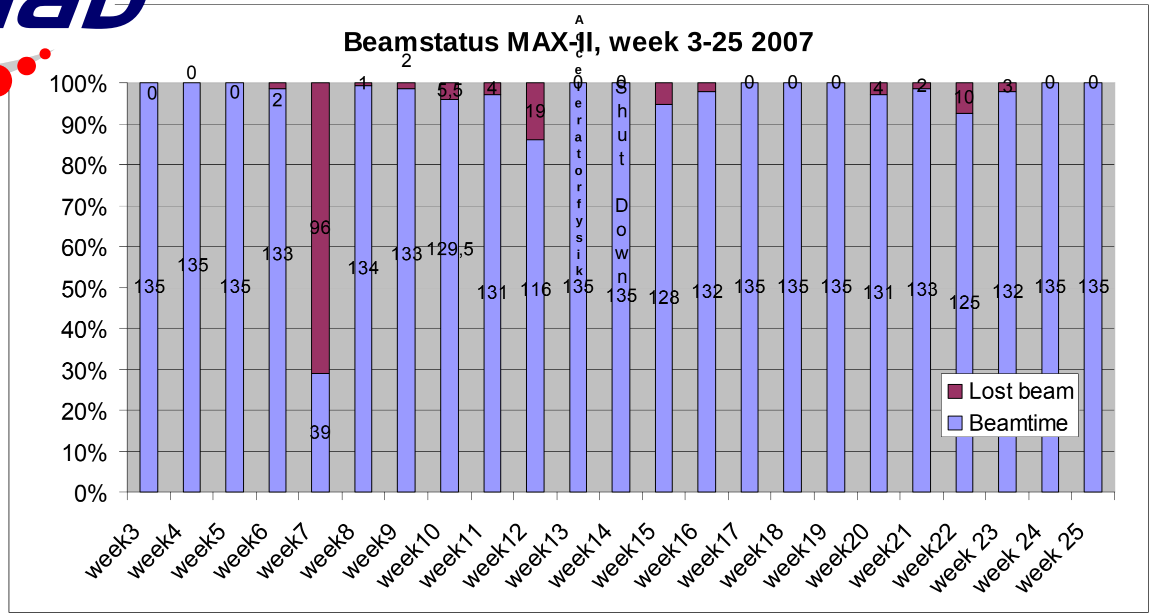
BPM system



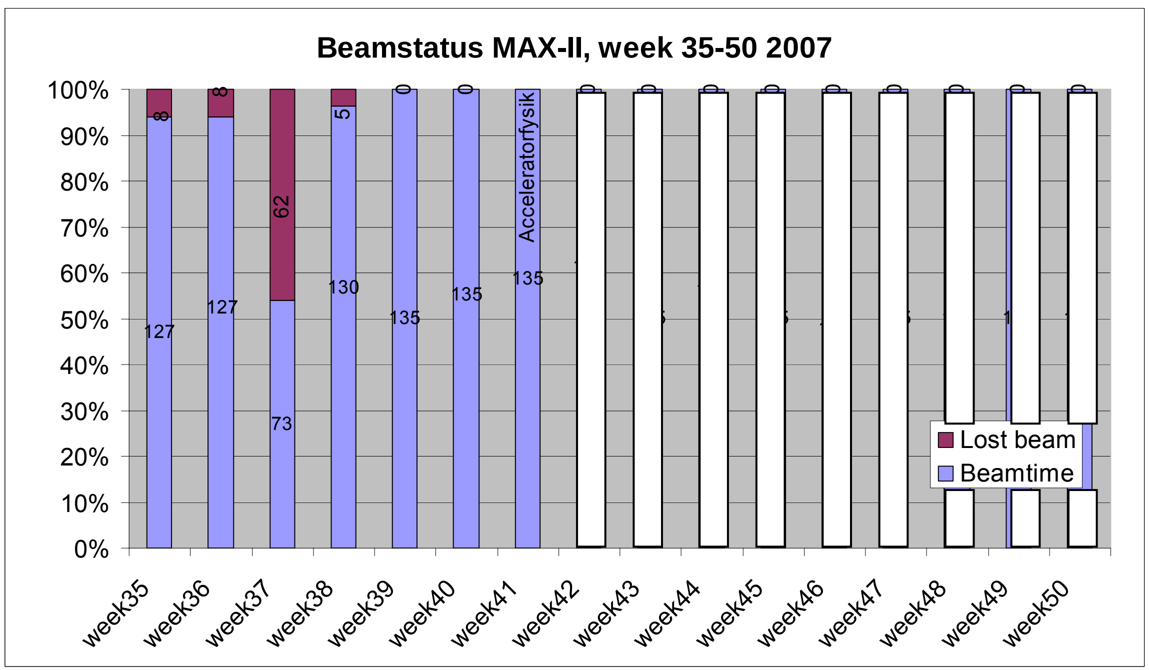
The BPM receivers are working at the third harmonic. This minimizes the risk of 100 MHz leakage from the transmitters and FM-band broadcasts.
Resolution << 1μm

MAX II measured parameters, with IDs engaged

Horizontal emittance (mrad)	8.71x10-9
Vertical emittance (mrad)	9.78x10-11
Momentum compaction	3.91x10-3
Coupling	0.011
Bunch length (1s) (s)	1.5x10-10
Energy spread (1s)	1.98x10-3
Horizontal beam size (m)	79x10-6
Vertical beam size (m)	31x10-6
Dispersion at D111 (m)	2.47x10-2
Dispersion at D111 (m)	-6.43x10-3
Horizontal tune	9.24
Vertical tune	3.18
Horizontal chromaticity	5
Vertical chromaticity	1.2



Beamstatus MAX-II, week 3-25 2007
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
week3
week4
week5
week6
week7
week8
week9
week10
week11
week12
week13
week14
week15
week16
week17
week18
week19
week20
week21
week22
week 23
week 24
week 25
135
135
135
133
39
134
133
129,5
131
116
135
135
128
132
135
135
135
131
133
125
132
135
135
0
0
0
2
96
1
2
5,5
4
19
0
0
0
0
0
4
2
10
3
0
0
Acceleratorfysik
Shut Down
Lost beam
Beamtime

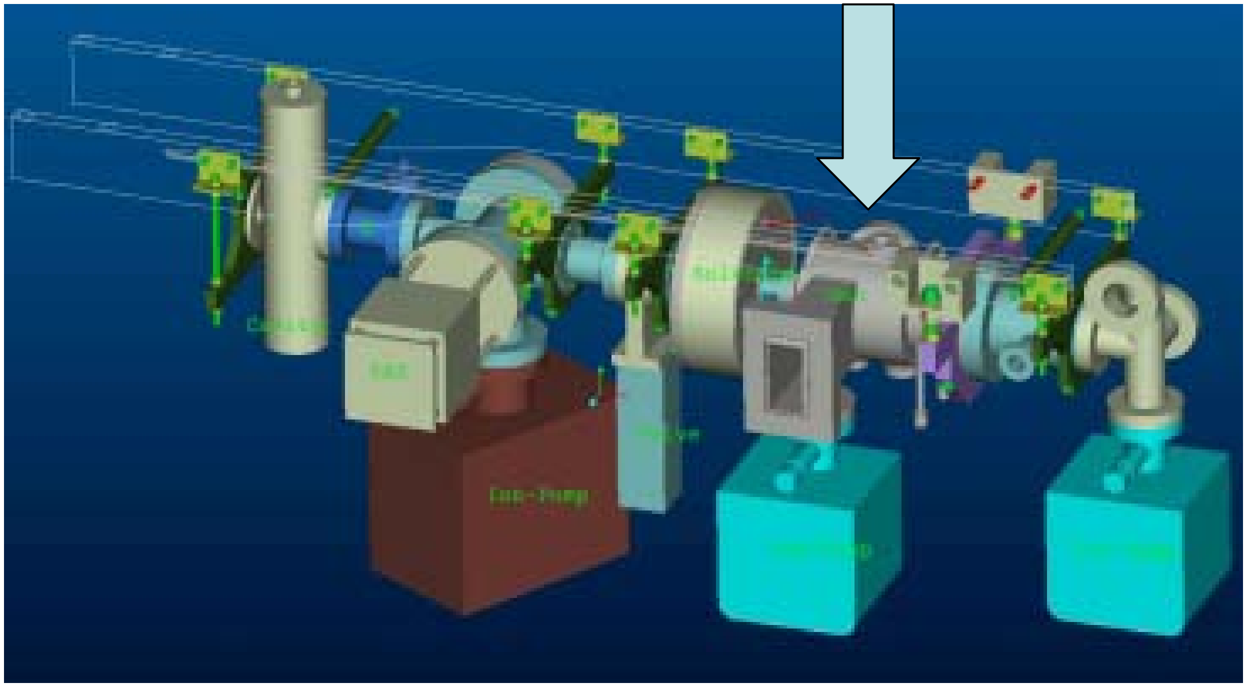


Beamstatus MAX-II, week 35-50 2007
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
week35
week36
week37
week38
week39
week40
week41
week42
week43
week44
week45
week46
week47
week48
week49
week50
127
127
73
130
135
135
135
8
8
62
5
0
0
Acceleratorfysik
Lost beam
Beamtime

A new pre-injector for the MAX injector

- The main motivation to design a new pre-injector is the high radiation levels due to low injection efficiency. Some areas is not allowed to enter during injections.
- Today a 3 GHz thermionic RF-gun with energy filter is used as pre-injector.
- The efficiency is never larger than 10% and often lower.
- The design goal is to increase the injection efficiency a factor of 5.
- Having 50% injection efficiency decreases the radiation level a factor of 5.
- High efficiency means also decreased filling time for the rings.
- The new electron source will consist of a 400 kV electron gun.

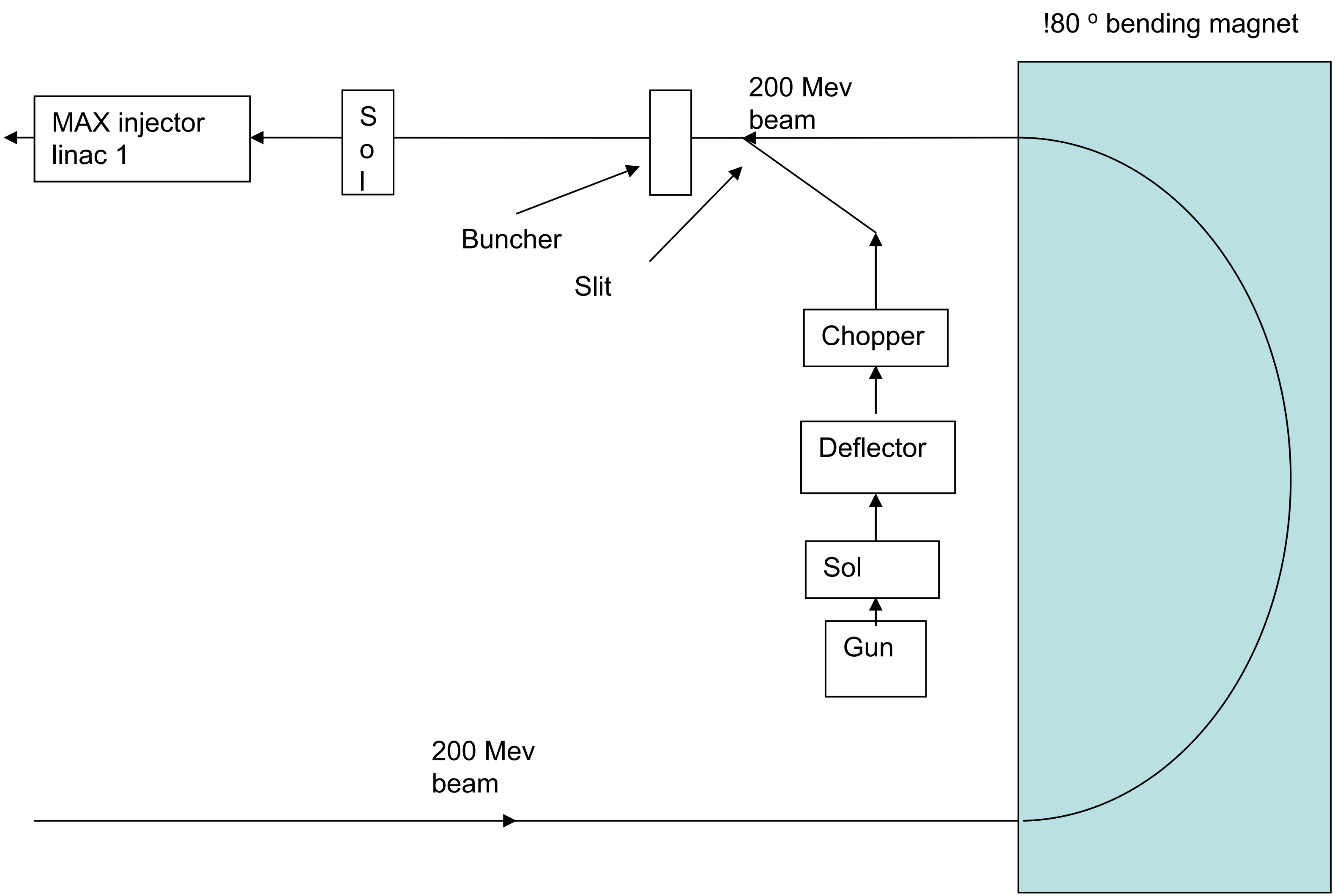
The pre-injector used today



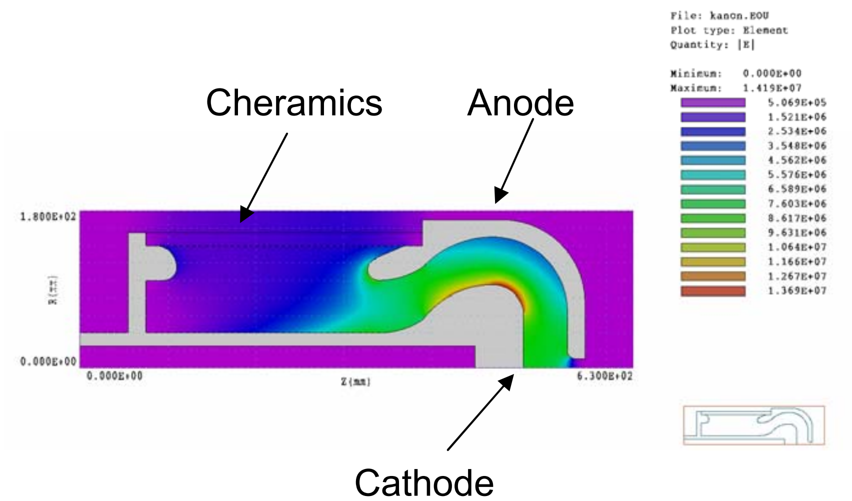
Specifications for the new pre-injector

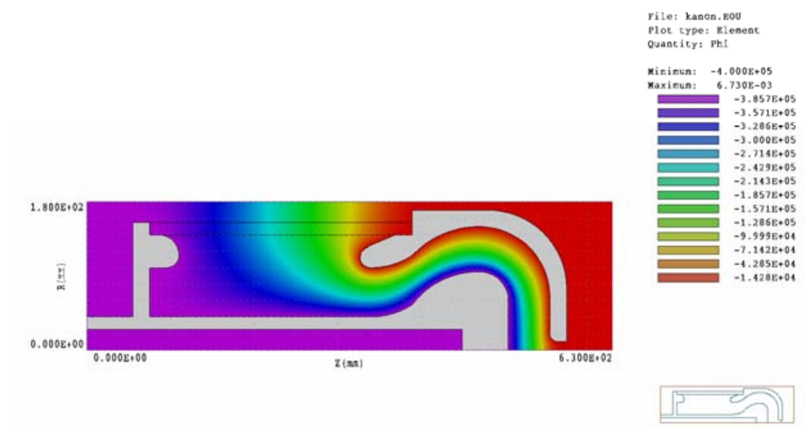
Electron energy	>400 keV
Pulse length	0-250 ns (variable)
Pulse current	>60 mA
Normalised emittance	<40 mm mrad (as in the former MAX I injection case)
Bunch energy spread	<10% (p-p) (not very important)
Max bunch length	20 ps (gives 2 % bunch energy spread, p-p).

The layout of the new pre-injector



The 400 kV electrostatic gun





A BaO cathode with a diameter of 7 mm will be used. This cathode is able to deliver 4 A, but only 1 A will be used for nominal operation. By using a larger cathode, we can afford to keep just the high quality centre of the beam, scraping off 75% at the first solenoid.

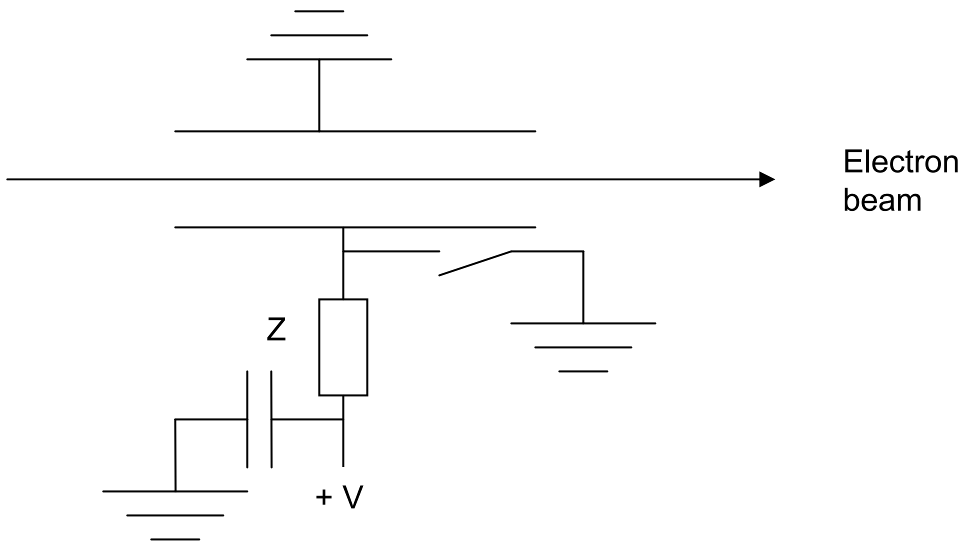
Modulator

Technical specifications	
Pulse output	
Peak power to electron gun	500 kW
Average power to electron gun	33W
Voltage range	0-400kV
Current range	1-10 Hz
Pulse length (FWHM)	2-4 µs
Top flatness	<±0.05% during 300 ns
Rate of rise	200-500kV/ µs
Amplitude stability	<±0.1
Trigger delay jitter	<±3
Internal dummy load	
Filament	
Max voltage	15V
Max current	10A

Solide state modulator

Deflector

Pulse shaping: Two parallel electrodes placed just in front of the solenoid are arranged as seen below. One electrode is grounded and the other one is connected to a voltage source via a terminating resistor. This electrode can be grounded with a fast switch.



Pulse-shaping arrangement.

Chopper cavity and slit

The radius of the beam at the chopping slit is 1.15 mm and the slit should have a width equal to the double beam radius. The beam centre will move to one side of the slit during 30^o RF phase change.

The chopper should be placed at a focal point of the bending magnet, 73 mm in front of the magnet entrance, to get a parallel beam at the magnet exit.

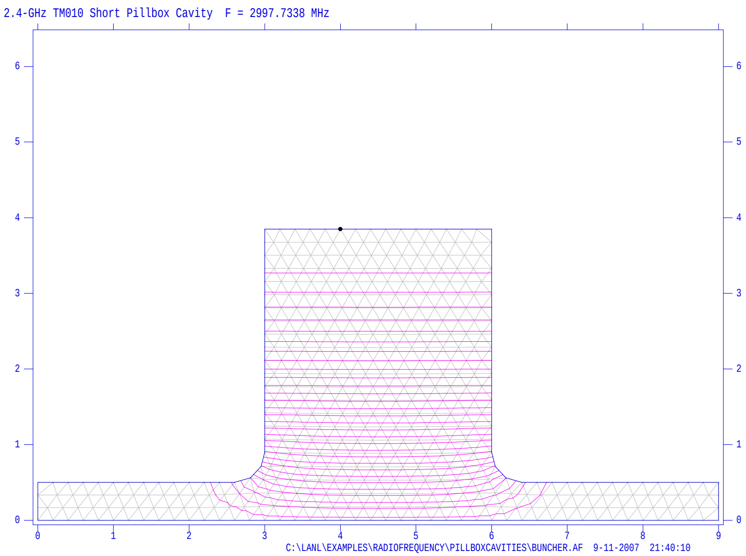
A capacity loaded cavity which decreases the magnet field strength will be used as a chopper cavity.

The pulse current after the slit is regulated with the chopper cavity voltage.

Cavity gap	1 cm
Capacitor diameter	2.5 cm
Shunt impedance	500 kΩ
Field strength	400 kV/m
Gap voltage	4 kV
Power	<10 W

The 3 GHz Buncher Cavity

Field normalization (NORM = 0): EZERO = 1.00000 MV/m
Frequency = 2997.73383 MHz
Particle rest mass energy = 938.271998 MeV
Beta = 1.0000000
Normalization factor for E0 = 1.000 MV/m = 15631.960
Transit-time factor Abs(T+iS) = 0.7733637
Stored energy = 0.0014923 Joules
Using standard room-temperature copper.
Surface resistance = 14.28426 milliOhm
Normal-conductor resistivity = 1.72410 microOhm-cm
Operating temperature = 20.0000 C
Power dissipation = 2016.0164 W
Q = 13942.2 Shunt impedance = 44.642 MOhm/m
Rs*Q = 199.155 Ohm Z*T*T = 26.700 MOhm/m
r/Q = 172.356 Ohm Wake loss parameter = 0.81159 V/pC



MAX-lab

The 3 GHz power source for the buncher cavity

Maximal output power 2.4 kW 4 μs but only 800 W is needed.

Beam size variations from gun to linac