

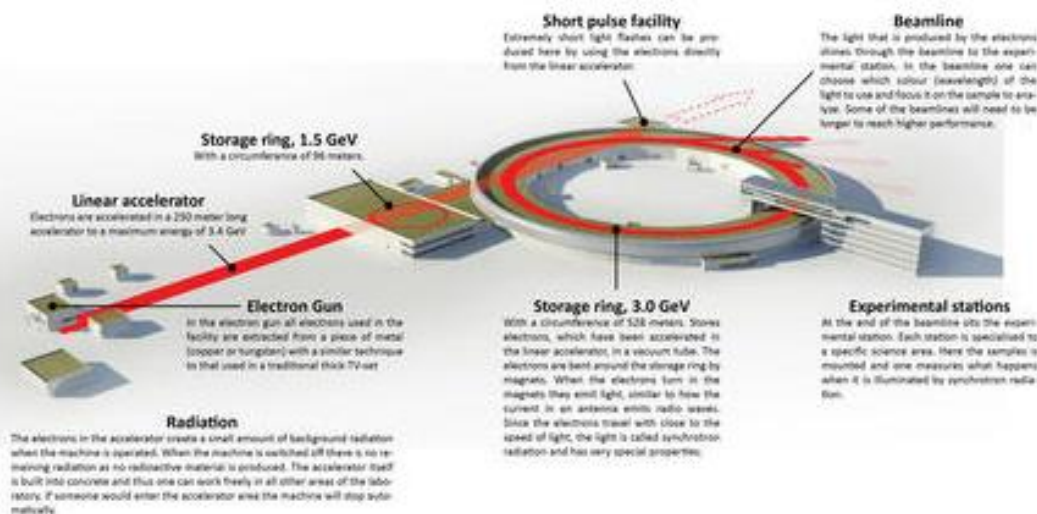
MAX IV LINAC

An aerial photograph of the MAX IV Linac construction site. The central feature is a large, circular structure under construction, surrounded by various buildings, parking lots, and construction equipment. A multi-lane highway runs along the left side of the site. The surrounding area includes fields and some trees.

RF power and acceleration on
MAX IV Linac

MAX IV Laboratory

MAX IV



Circumference of MAX IV, 3GeV, 528m

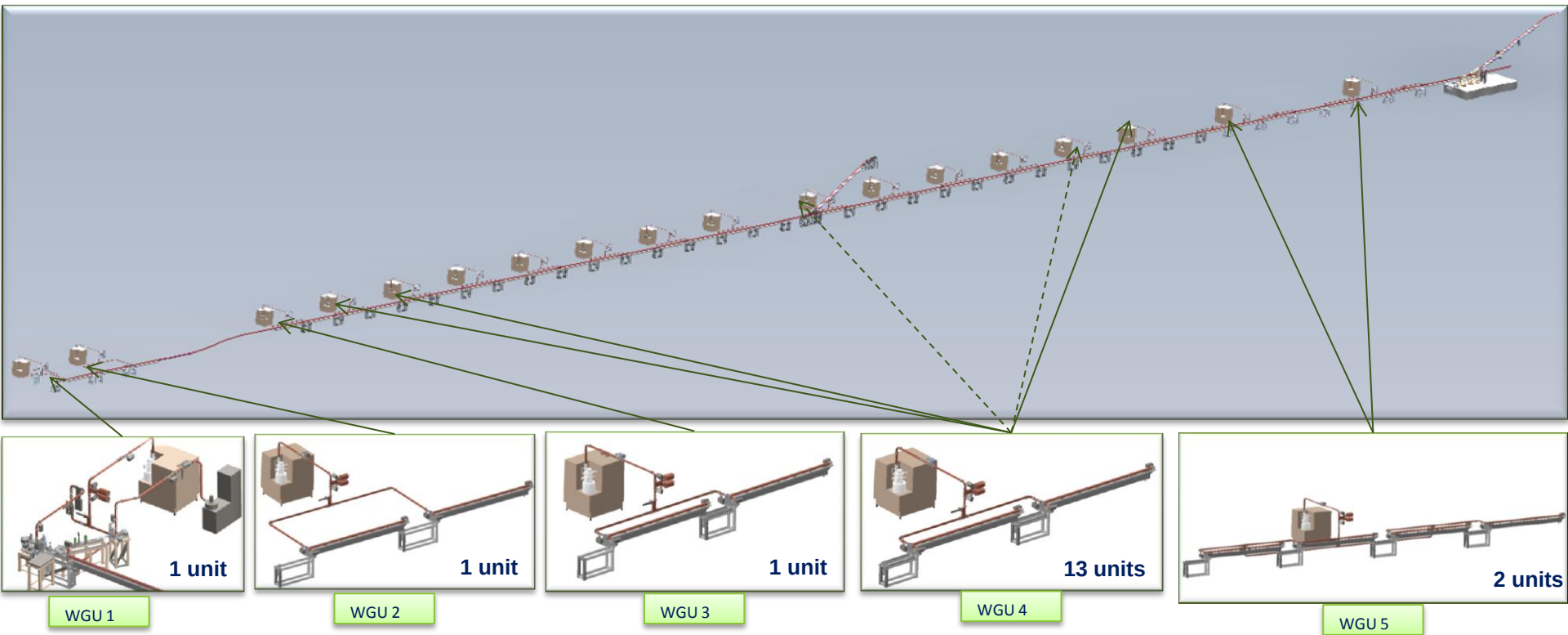


Circumference of Colosseum 527m

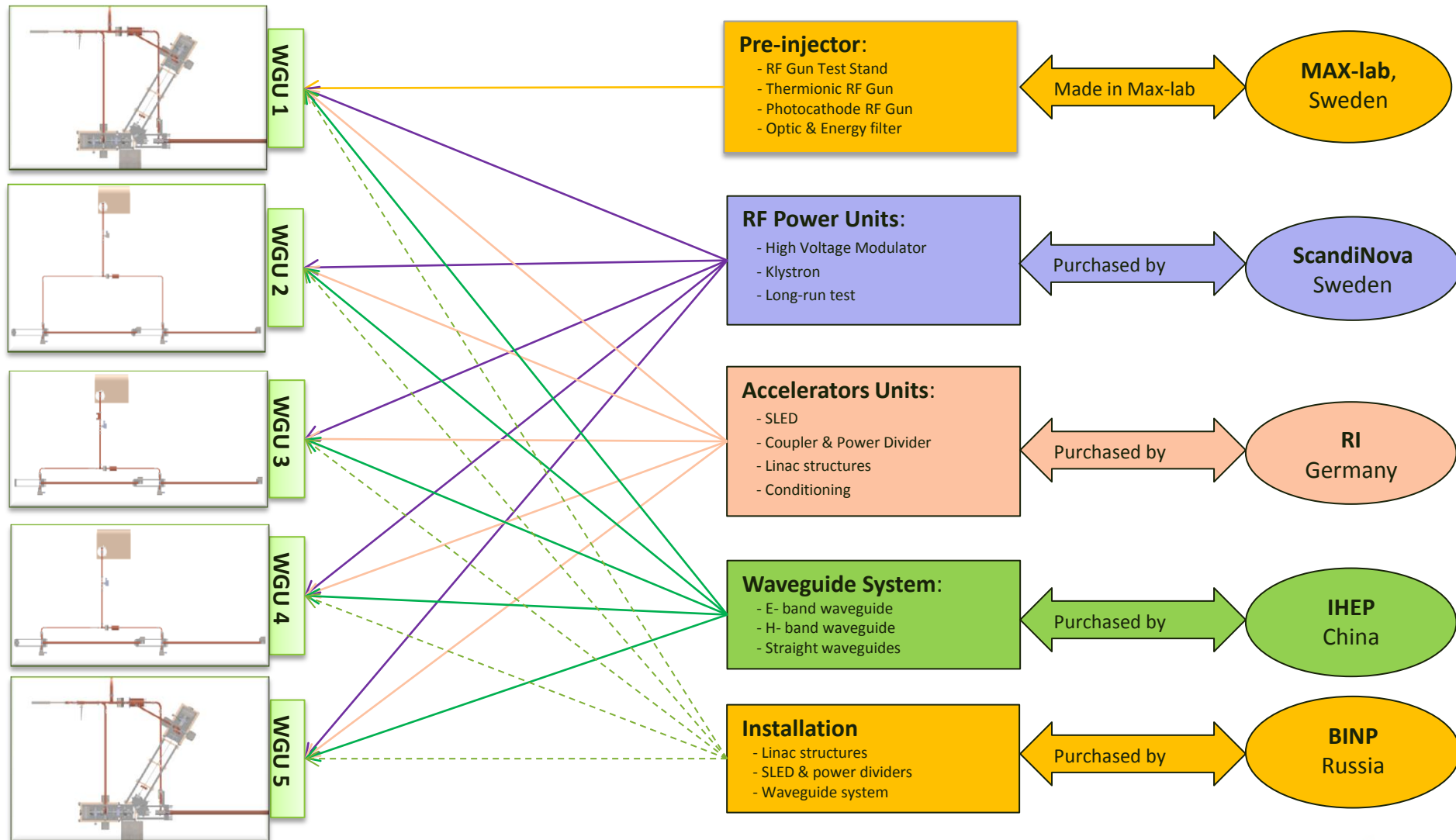


MAX IV 3GeV LINAC

- 18 pcs: RF power units (37MW peak, 4,5usec, 100Hz), ScandiNova mod + Toshiba klystron
- 1 pc: RF power unit (8MW peak, 3usec, 10Hz), ScandiNova mod + Thales klystron
- 18 pcs: SLED (Q=100000, 4,5usec in, 0,7usec out), RI
- 2 pcs: RF guns (a thermionic, second photocathode), MAX IV Laboratory
- 39 pcs: Linac struction (max gradient of acceleration 25MV/M, 5m long), RI

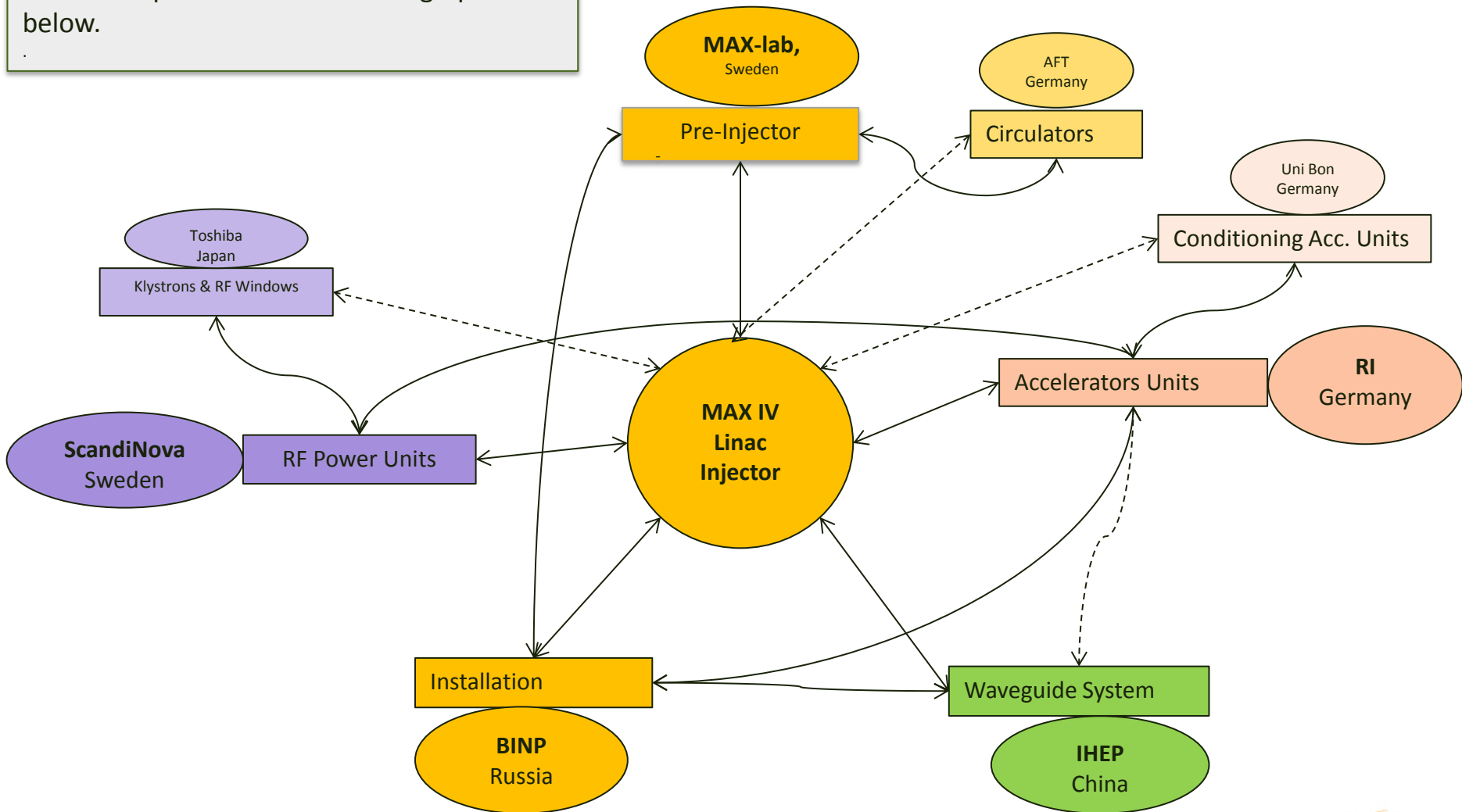


MAX IV LINAC



MAX IV LINAC

⌘ Despite our efforts, have been not been able to simplified more than that graph below.



Pre-Injector

RF Power Unit

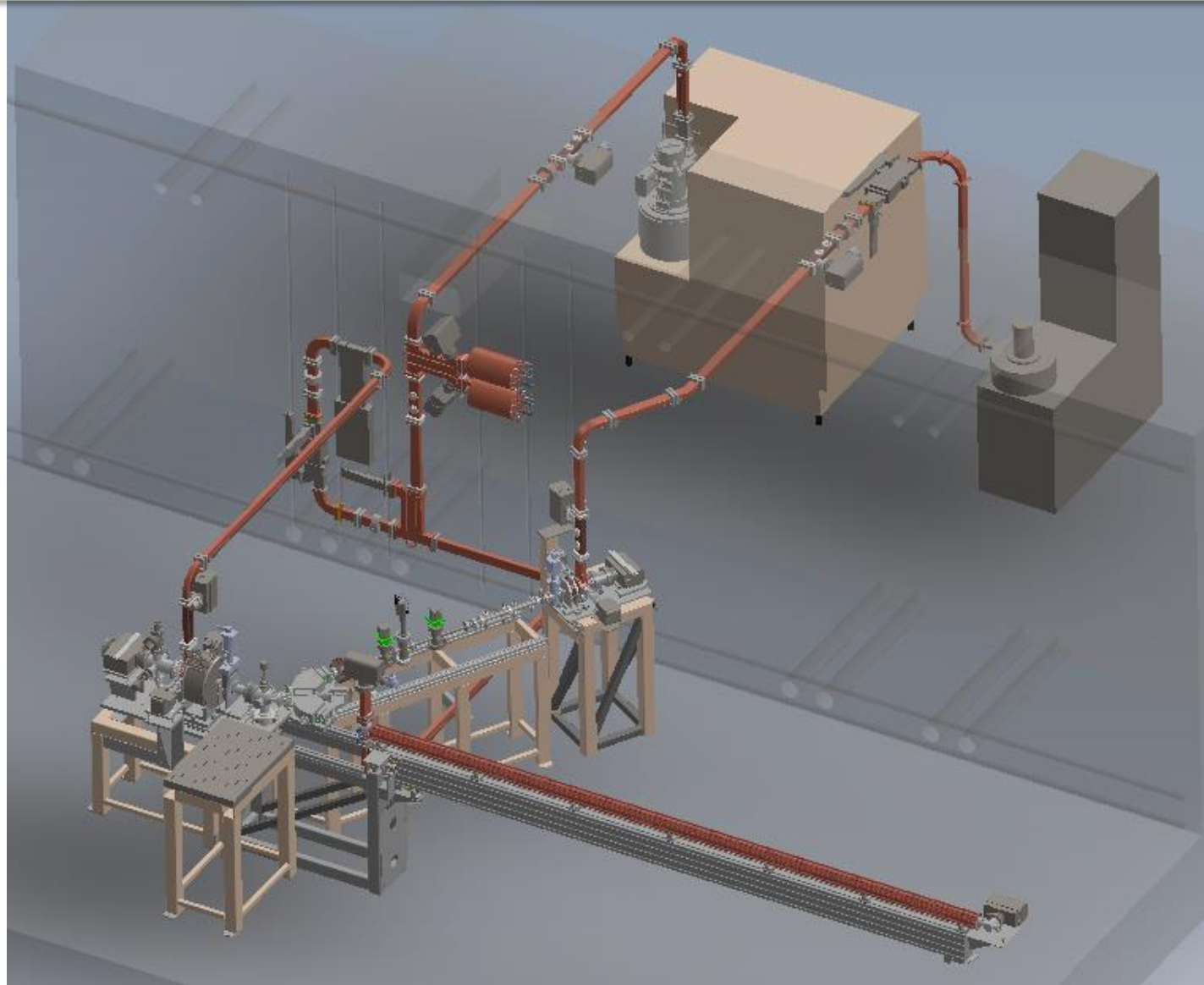
Accelerator Unit

Waveguide system

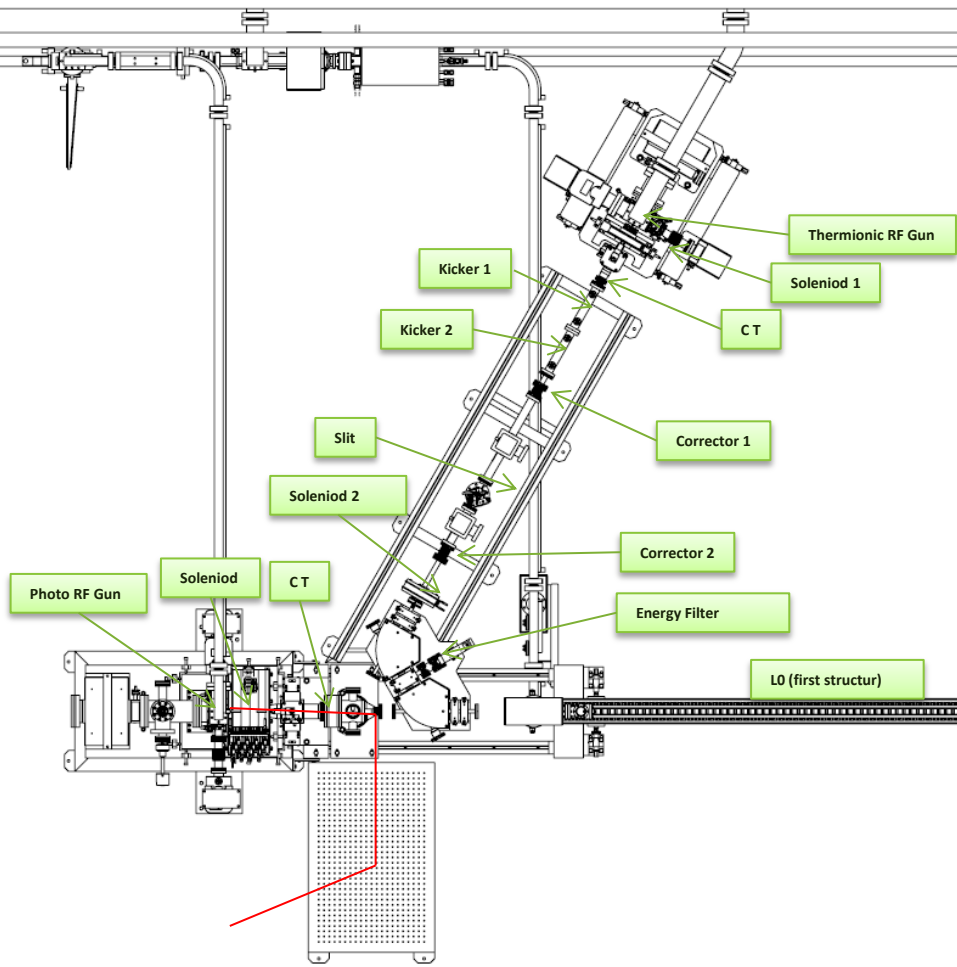
- MAX IV pre-injector
- RF Gun Test Stand at MAX-lab
 - Thermionic RF Gun
 - Photocathode RF Gun
 - Optic & Energy filter

MAX IV Pre-Injector

- Two RF units
- Two RF Guns
- One SLED
- One Linac structure
- Waveguides



MAX IV Pre-Injector



✕ The MAX IV pre-injector will cover two modes of running:

1. Thermionic RF Gun

- Thermionic gun will only be used for ring injections.
- The bunches are leaving the gun with a period of 333 ps (3 GHz).
- Storage ring cavities are operating at 100 MHz. Wanted bunch train structure
- A bunch train should consist of 3 bunches, appearing with a period of 10ns (100 MHz).
- 10 bunch trains during one LINAC shot (100ns).
- The max PRF - 10Hz.

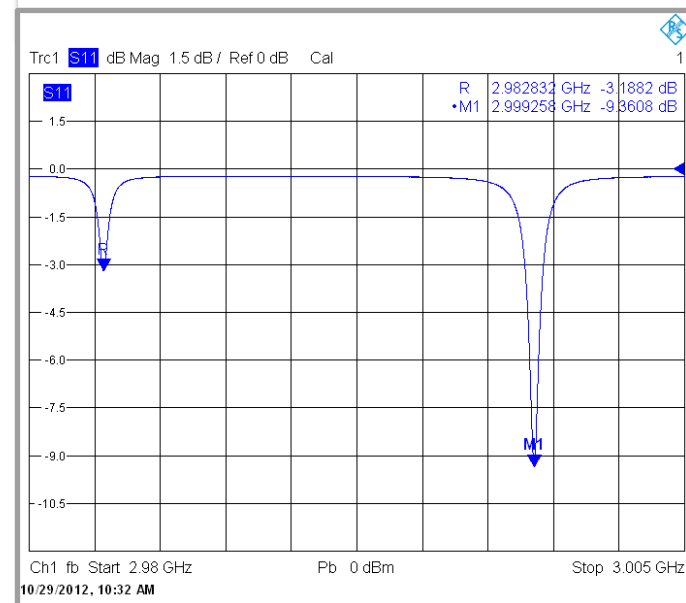
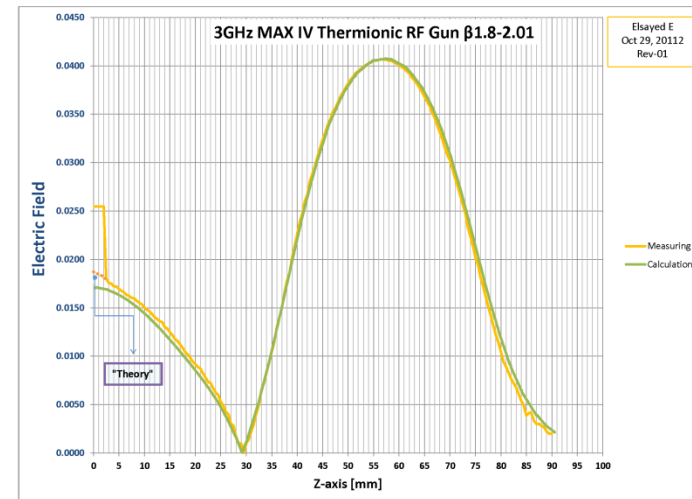
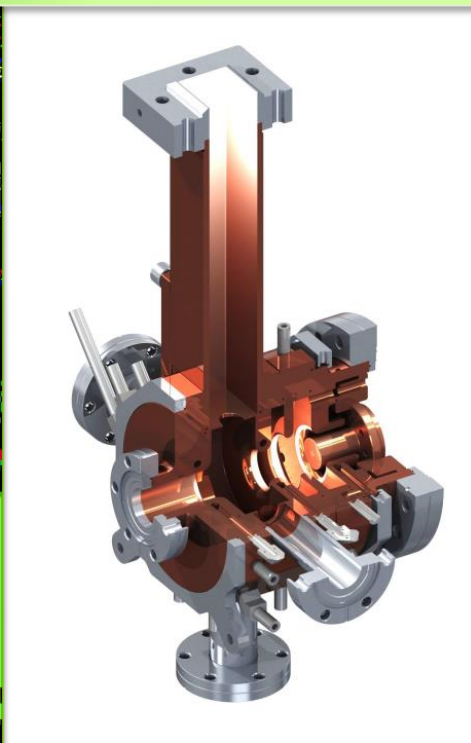
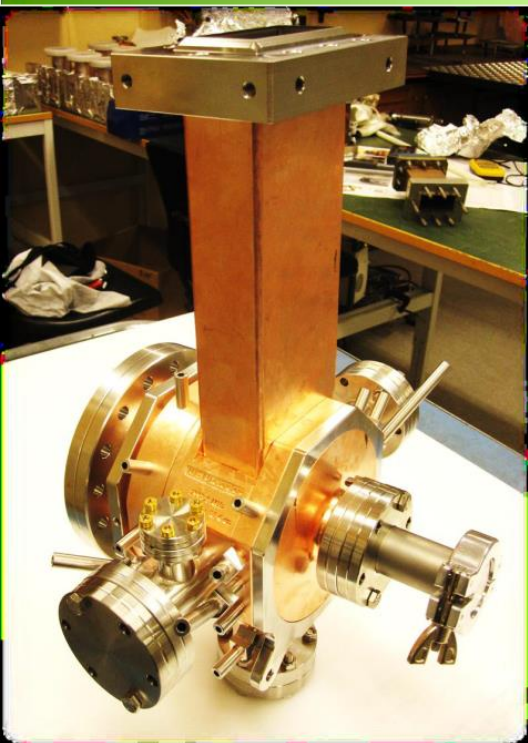
2. Photocathode RF Gun

- Photocathode RF Gun will be used for the SPF and FEL application.
- The short bunches are living gun with extension on time 1-2ps
- The beam energy 4,5 to 5MeV
- The beam charge 20 to 1000pC
- The max PRF -100Hz

3. The beam optic & energy filter will take care to have the proprio electron bunch to the input of L0 for the rings injection as well as for the SPF &FEL applications.

✕ Both of RF Guns will be tested and characterized before installation on MAX IV injector.

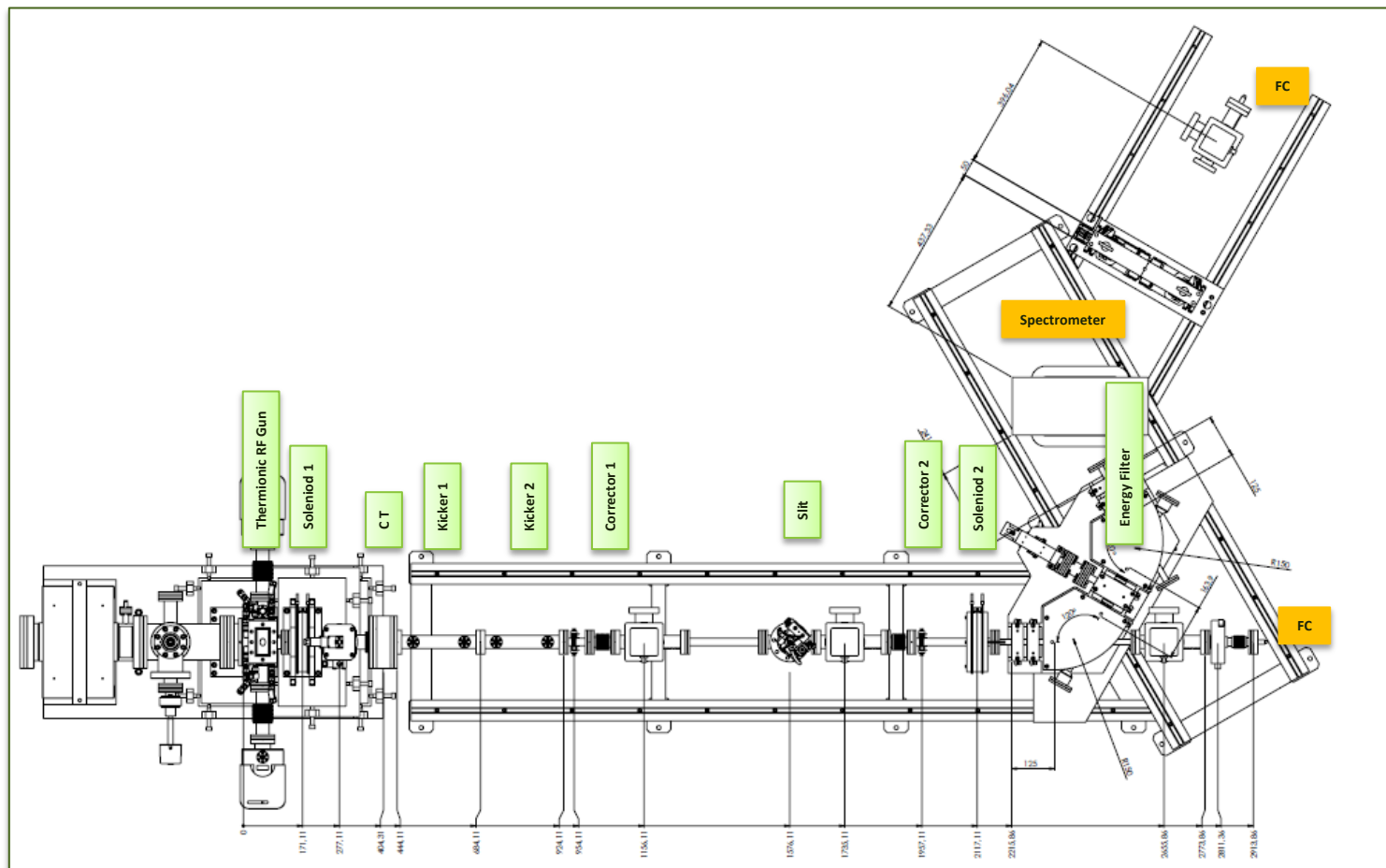
Thermionic RF Gun



Aperture	Current before Energy filter / mA	Current after Energy filter / mA
Out	206	68
1 mm	23	13
2 mm	59	33

Thermionic RF Gun Test Stand

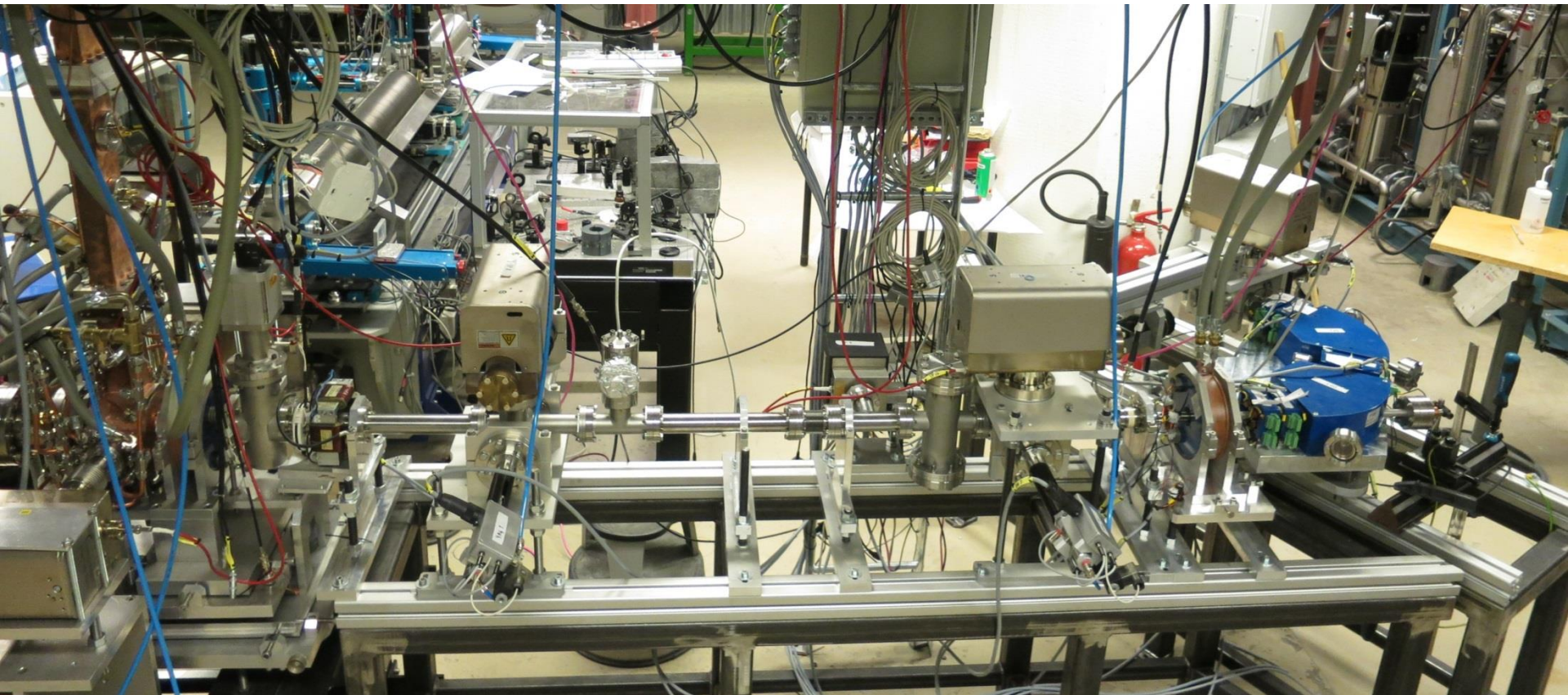
✂ The configuration of Thermionic RF Gun test stand is similar (identical) as it is build in MAX IV pre-injector.



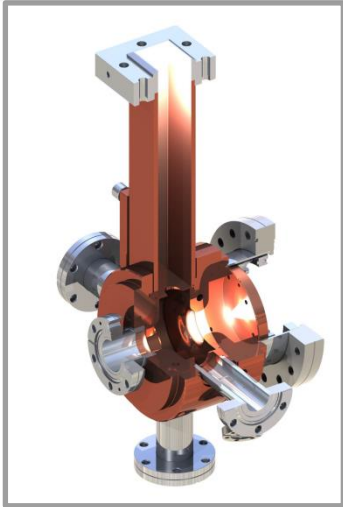
Thermionic RF Gun Test Stand

✕ The Thermionic RF Gun Test Stand helps on doing:

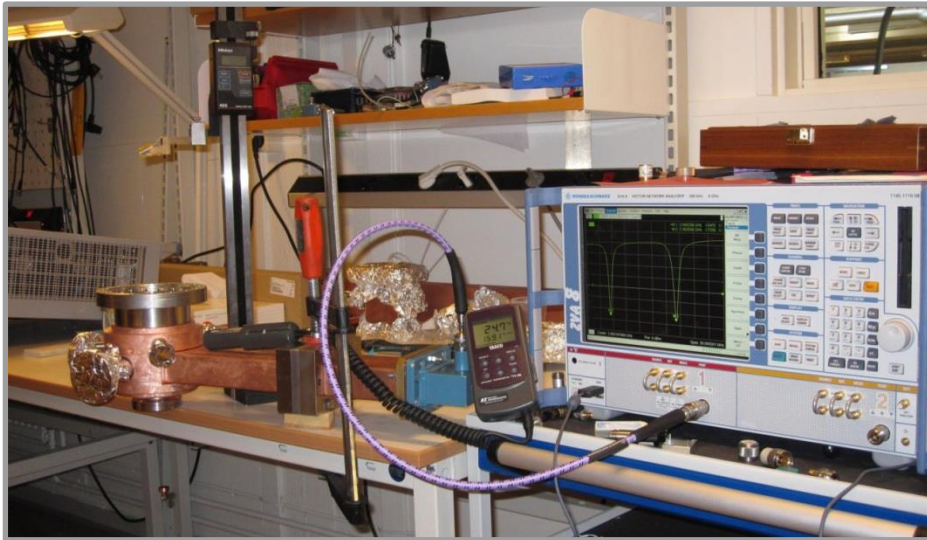
1. Gun conditioning
2. Measurements of RF Gun: electrical field, beam charge and energy
3. Testing bpm system
4. Emittance of Gun electron beam.



Photocathode RF Gun

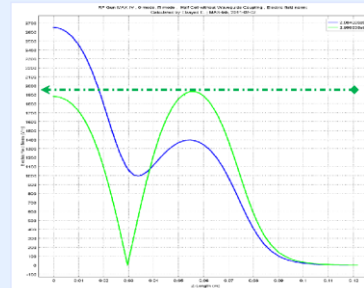


⌘ The Photocathode RF Gun is designed, constructed, tested on test stand in MAX-lab. External forms and contacts with ion pumps and RF power are the same for both Photocathode and for Thermionic RF Guns, so we can easily use almost the same components of RF Gun Test Stand.



RF Gun Parameters at 40°C in Vacuum

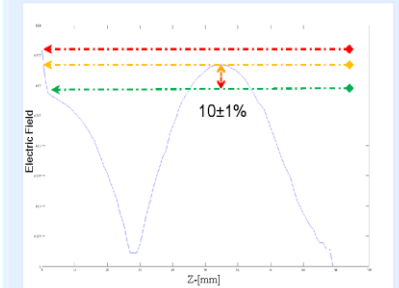
Parameter	Simulation Value
π mode f	2998.538 ± 0.3 MHz
θ mode f	2984.006 ± 0.3 MHz
Mode separation	14.532 MHz
Q_0	12966



π mode f 2998.538 MHz

RF Gun Parameters at 25.1°C in Air

Parameter	Measured Value
π mode f	2998.358 MHz
θ mode f	2983.598 MHz
Mode separation	14.76 MHz
Coupling β	1.66

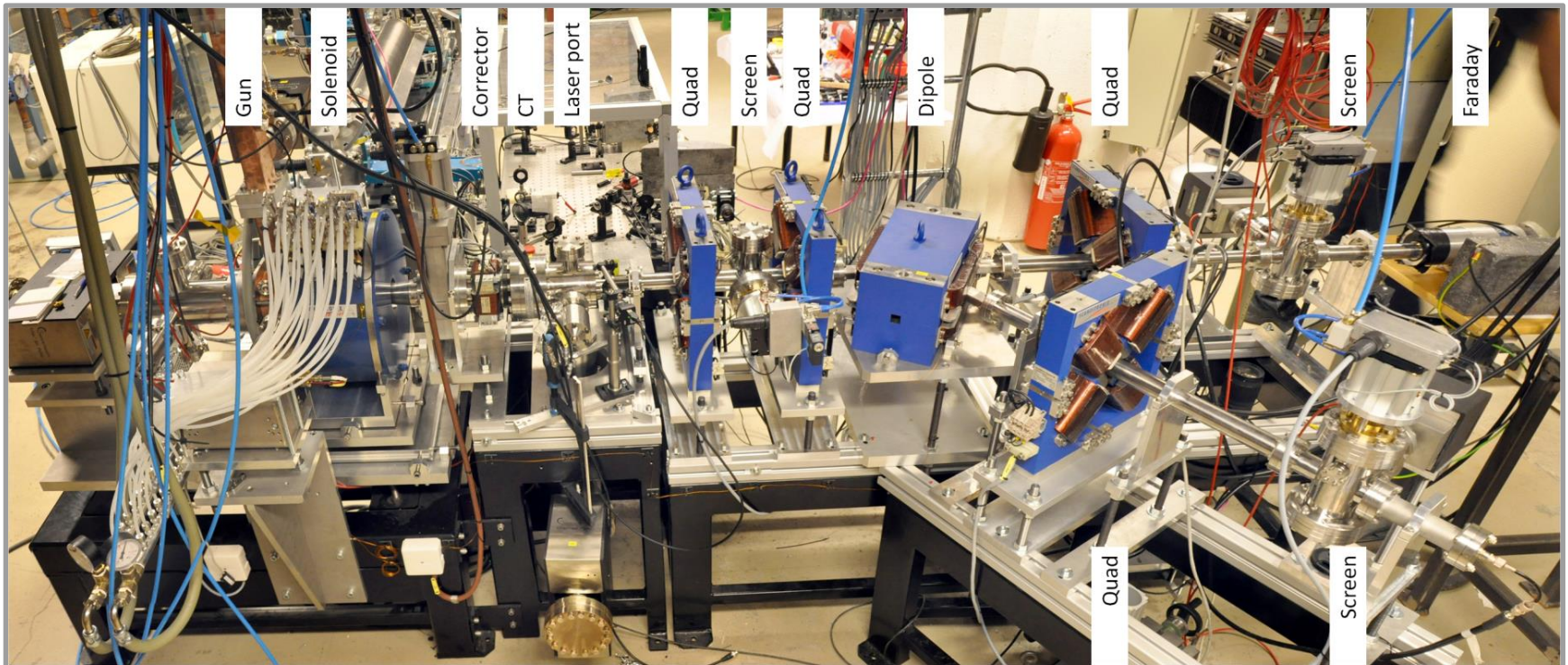


π mode f 2998.358 MHz

Photocathode RF Gun Test Stand

✧ The Photocathode RF Gun Test Stand helped on doing:

1. Gun conditioning
2. Measurement of electrical field, charge and beam energy
3. Measurement of electron beam's Emittance

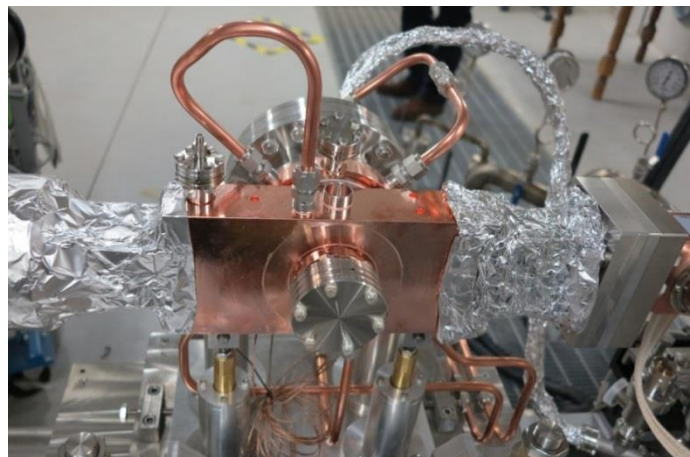
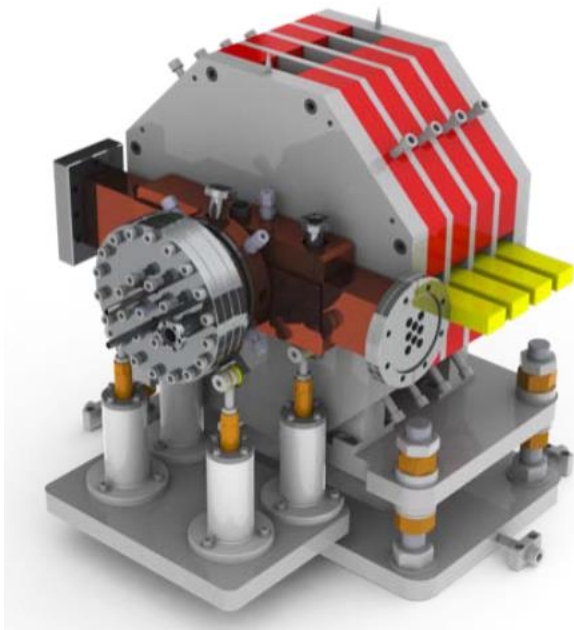


Next photocathode “LCLS” type RF Gun

Next Photocathode RF Gun, will be build at Max-lab (model RBT/UCLA version of “LCLS type” gun)

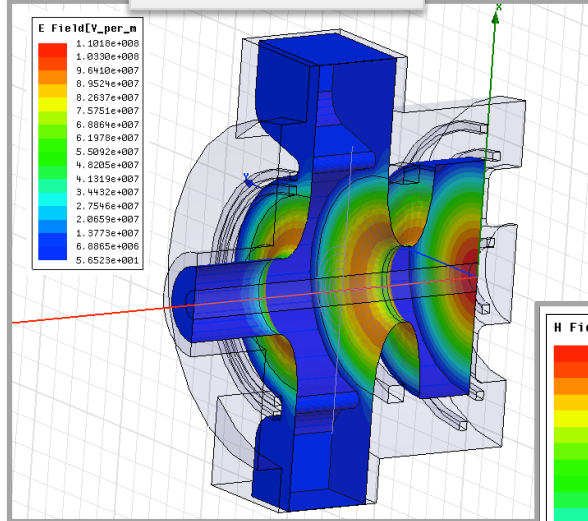
The specific improvements are:

1. Dual RF feed
2. A racetrack shape in full cell
3. Increased the mode separation from 3 to 15MHz
4. The iris between two cells was reshaped to reduce its surface field
5. Z-coupling and increasing the radius of the edges
6. Reduced size deformation tuners
7. Improved cooling channels
8. New cathode mounting
9. Dipole and quadrupole field correctors in the magnetic solenoid
10. A bucking coil to cancel the small magnetic fiels at the cathode

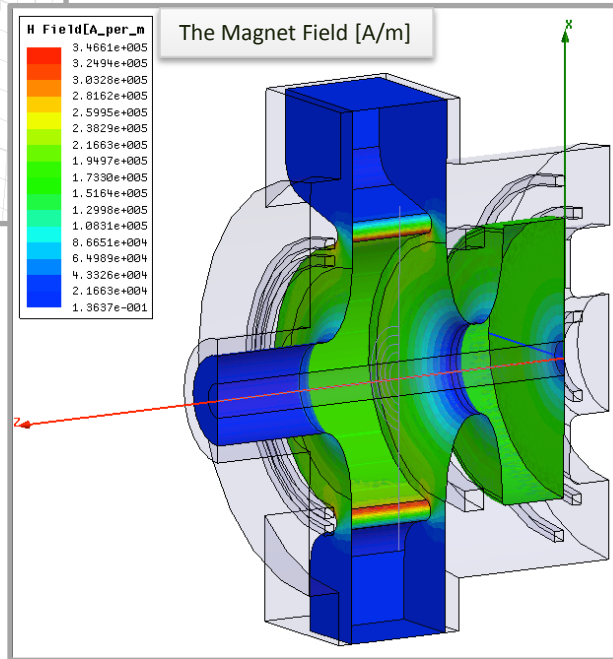


Photocathode “LCLS” type RF Gun

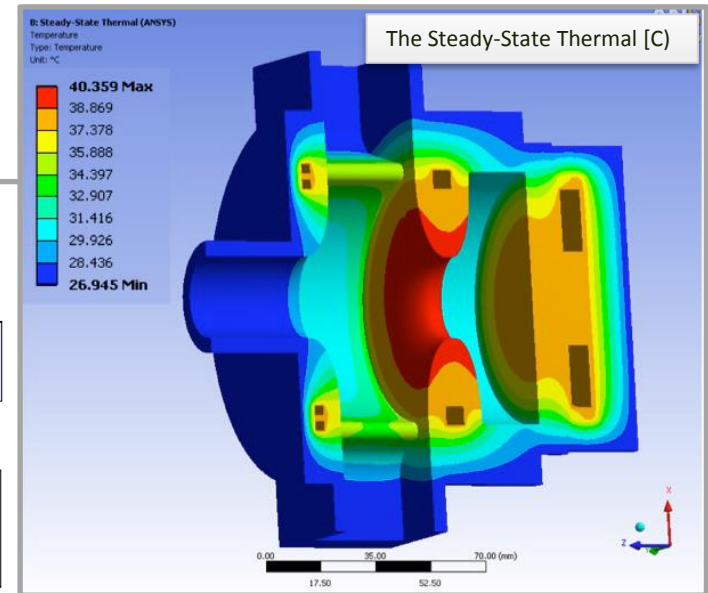
The Electrical Field [V/m]



The Magnet Field [A/m]

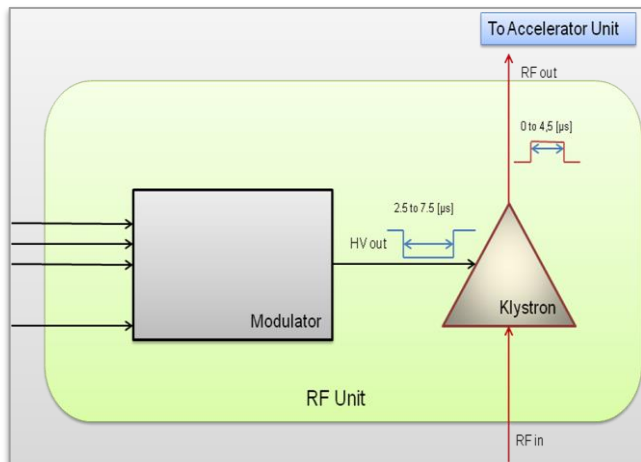


The Steady-State Thermal [C]



Pre-Injector RF Power Unit Accelerator Unit Waveguide system

✧ 18 pcs SCN modulator K2, Toshiba klystrons model E37310,
✧ 1pc SCN modulator K1, Thales klystron Th2157.



✧ Three principal concepts:
1. Spit Core
2. Parallel Switching
3. Pulse to Pulse Control



SCN Mod. K2 & Toshiba Kly. E37310

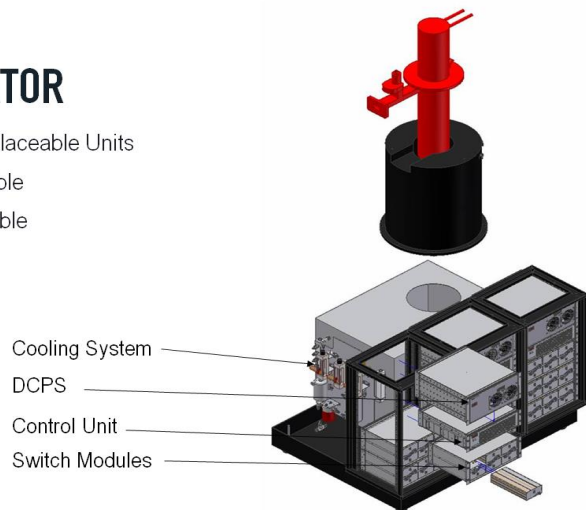
Nr	Parameter	Unit	Value
1	RF frequency	MHz	2998,5
2	Max. Peak RF Output Power	MW	35 - 37
3	Max. Klystron Average RF Power	kW	16 -18
4	RF flat top pulse width variable	μ s	0 to 4.5
5	Voltage Pulse width variable (80%)	μ s	2.5 to 7
6	Pulse Repetition Frequency variable	Hz	0 to 100
7	Flat top ripple or droop	%	$\pm 1,5$
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

K2 MODULATOR

FRU – Field Replaceable Units

Modular – Scalable

Flexible - adaptable



α MAX-lab K2 Modulator Pulse 290kV/4.5 μ s



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%. ^(*)

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

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

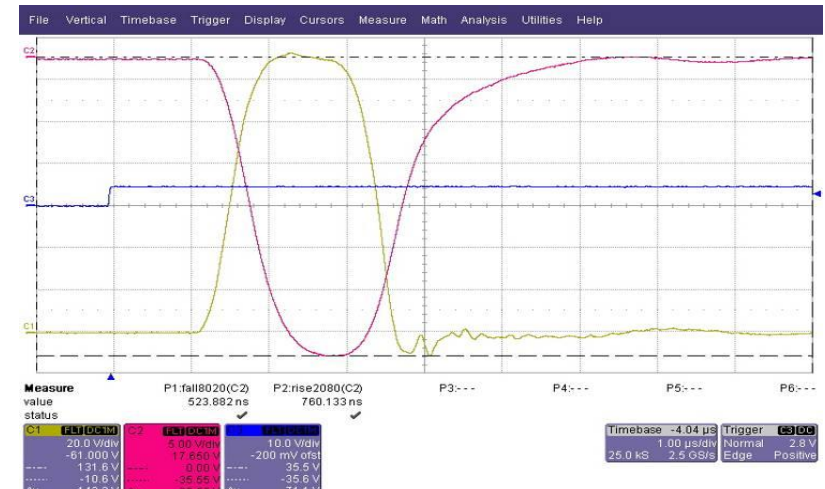


SCN Mod. K1 & Thales Kly. TH2157

⌘ RF unit with 8MW peak, 3us, 10Hz for the for the Thermionic RF Gun.



⌘ MAX-lab K2 Modulator Pulse 290kV/4.5μs



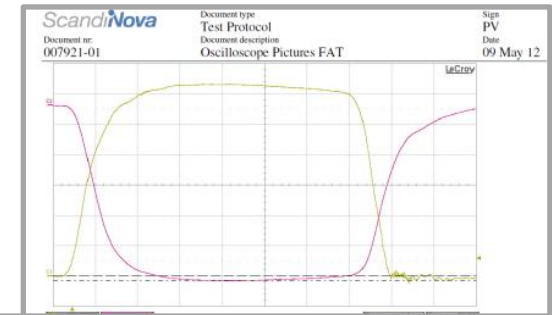
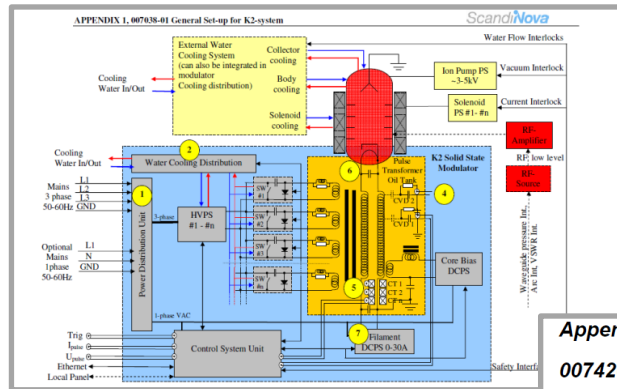
OPERATIONAL PARAMETERS

Pulse Output		Unit		Notes
	Modulator Peak power	MW	18,7	
	Modulator Average power	W	800	
	Operational Voltage range	kV	170	see fig above.
	Operational Current range	A	140	see fig above
	PRF range	Hz	1-10	Subject to average power
	Pulse length (top)	μs	1-3	Subject to average power
Filament Output	Top flatness (dV)	%	<±1	0,1% within 1μs
	Rate of rise	kV/μs	150-250	Measured at 50% of Peak voltage
	Amplitude stability	%	<±0.01	
	Trig delay	μs	~1.2	See fig above
	Pulse to Pulse time jitter	Ns	<±4	
	Pulse width time jitter	Ns	<±8	
	Max voltage DC	VDC	15	Adapted to Klystron data sheet
	Max Current DC	ADC	15	Adapted to Klystron data sheet

RF units, Factory Acceptance Test (FAT)

FAT (Factory Acceptance Test)

- All delivered modulators, have passed Acceptance Factory Test (AFT) .
- FAT contains 7 appendixes documents:
 - 1.Set-Up for the K2 conditioning,
 - 2.List of Instruments,
 - 3.Operating Conditions,
 - 4.Oscilloscops Curves,
 5. Settings and Limits
 6. Pulse Stabilities Measurements, 7. Stability records pulse to Pulse



Appendix 6

007420-00 Pulse stability measurement

Measurement Method 1

The Pulse to Pulse data was measured... designed by Scandinaova System... terminated by... all scal...

Scandinaova
Document type: Test Protocol
Document description: Factory Acceptance Test Record K2
Document no: 012047-00
Revision: 01/2013-00
Date: 27 Dec 11

Factory Acceptance Test
Solid State Modulator K2, Mod. No: 010247-00
Customer: Max Lab
Serial No: 1
Scandinaova Project number: 586

Scandinaova
Document type: Settings and Limits
Document description: List of Instruments FAT
Document no: 007039-02
Revision: 01/2013-00
Date: 27 Dec 11

Settings and Limits
Customer: Max Lab
Project no: 010247-00
Module: 001

SCN	Type:	Mar
4-2520	Oscilloscope	Le
0051	Multimeter	F
0109	Power Meter	
0101	Clamp meter	

Appendix 7: 007005-00 Stability Record Pulse to Pulse

Sample	WFO	2nd	3rd	4th	5th	6th	7th	8th
1	7820	7820	7820	7820	7820	7820	7820	7820
2	7820	7820	7820	7820	7820	7820	7820	7820
3	7820	7820	7820	7820	7820	7820	7820	7820
4	7820	7820	7820	7820	7820	7820	7820	7820
5	7820	7820	7820	7820	7820	7820	7820	7820
6	7820	7820	7820	7820	7820	7820	7820	7820
7	7820	7820	7820	7820	7820	7820	7820	7820
8	7820	7820	7820	7820	7820	7820	7820	7820
9	7820	7820	7820	7820	7820	7820	7820	7820
10	7820	7820	7820	7820	7820	7820	7820	7820

Model	Calibr	Status	Calibrated	Next calibration
Yes	Calibrated	2011-11-28	2012-11-28	2012-06-13
Yes	Calibrated	2011-06-13	2012-12-12	2012-10-14

RF units, Site Acceptance Test (SAT)

RF Power Units Site Acceptance Test (SAT), have been started from 16/09 -13.
Running of RF Power Units will be on Diode Mode



Pre-Injector RF Power Unit Accelerator Unit Waveguide system

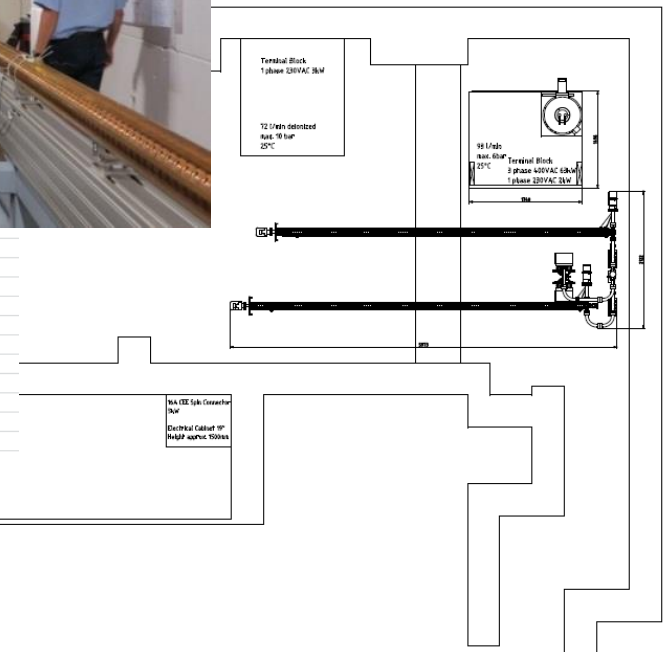
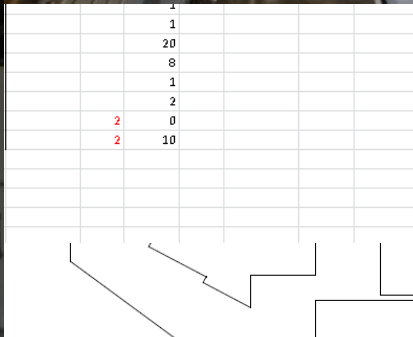
✕ 18 pcs SLED
✕ 40 pcs Linac structures
✕ all conditioned in factory

(6000 accelerators cups; 240
RF absorb cups, 38 SLED
cavities, 25 RF power dividers:
100%)



- ✧ Conditioning of Accelerator Units have been done in radiation protected area at Uni Bon.

21	Blind flange CF4
22	LIL CU Gasket
23	support for ion
24	support for ion
25	
26	ot
27	Ion Pump CF100
28	adaptor LIL7CPR
29	Waveguide Pie
30	Ion pump contro
31	cables for ion p
32	cold cathode 6 o
33	cables for CCG; 3
34	connector for io
35	coax feedthrou
36	Flowmeter 3x20
37	Mini-Circuits NF
38	pumstand
39	fiducials
40	

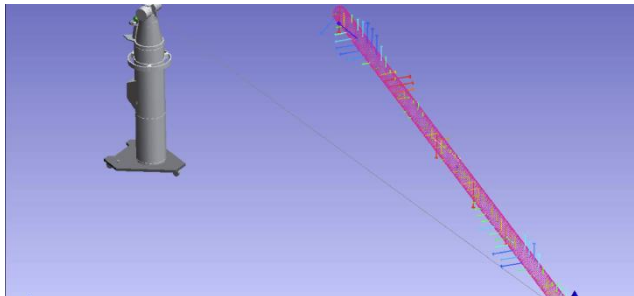
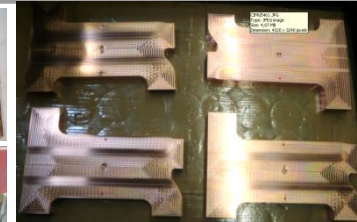


Acceptance Test Protocols

- MAX-lab possesses all documentation concern Factory Acceptance Test for all conditioned acc. Units. Every of these FAT, contain the with records, list of used instruments, operating conditioning, oscilloscope records, settings and limits, pulse flatness and pulse to pulse stabilities.
- Following is the list of the FAT documents.

Name ^	Date modified	Type	Size
3223 Unit 1 Acceptance Tests Protocols 201...			
3223 Unit 2 Acceptance Tests Protocols 201...			
3223 Unit 3 Acceptance Tests Protocols 201...			
3223 Unit 4 Acceptance Tests Protocols 201...			
3223 Unit 5 Acceptance Tests Protocols 201...			
3223 Unit 6 Acceptance Tests Protocols 201...			
3223 Unit 7 Acceptance Tests Protocols 201...			
3223 Unit 8 Acceptance Tests Protocols 201...			

Name ^	
..	B
Alignment	B
Bakeout	B
Conditioning Logfile	B
Leaktest	B
RF-Measurement	B
RGA	B
3223-BP-9248 RF Unit 8 Conditioning original.pdf	B
3223-BP-9269 Accelerating Unit 8 FAT complete.pdf	B



The phase plot shows the phase error relative to the first cell.

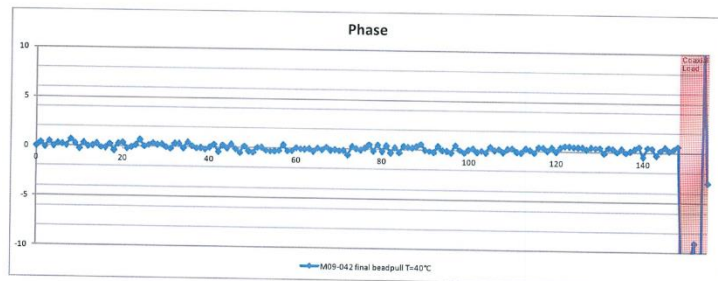
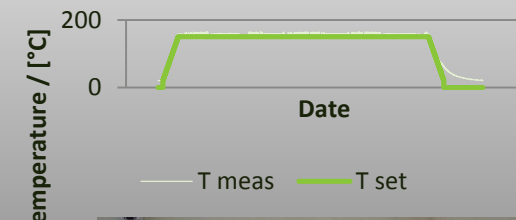


Figure 2-1 Phase Plot



Protokoll / Record			
Dichtheitsprüfung (Helium - Leck - Test)			
Projekt Nr. / Project No.	Blatt / Sheet	Fertigungs- und Prüfplan Nr. / Fabrication and Test Plan No.	Prüfschritt Nr. / Teststep No.
3223	1 von 1	1.3223-0100.25	AG 030
Artikelnummer / Article No.	Zeichnung Nr. Dok-ID / Drawing No. Doc-ID	Bezeichnung / Bauteil / Subassembly / Component Part	
P84803	Z141264	Doppel - Struktur System Unit 8	
Prüfung / Test			
Spezifikations-Nr. / Specification No.	N.A.	Ort / Place	RI BGL 19c
Prüfvorschrift-Nr. / Test Specification No.	N.A.	Datum / Date	15.11.2012
Prüfplan-Nr. / Test Sequence Plan No.	N.A.	Prüfer / Inspector	B. Haselbach
Material	diverse	Prüfumgebung / Scope of Testing	komplett v.d.Ausheizen
Anforderung / Requirement	LS <2,0E-09 mbar*l/s	Prüfart / Type of test	lokal

Bake Out Curve



Accelerator Unit in MAX IV Linac tunnel



Waveguide System

✕ The Waveguide System components have provide by IHEP, China.

QUOTATION FOR MAX IV WAVEGUIDE COMPONENTS (Updated July.20, 2012)

	Old No.	Item No.	Description	Qty	Price
1	WG0001	200877	Straight L=851,6	1	
2	WG0002	200880	Straight L=1252,5	17	
3	WG0003	200883	Straight L=1650	18	
4	WG0008	200886	Straight L=5905,6	4	3,
5	WG0010	200889	Straight L=2334	2	1,
6	WG0011	200892	Straight L=627,9	3	
7	WG0012	200873	E-Bend 200x266,7	36	
8	WG0013	200934	E-Bend 200x242,3	40	
9	WG0014	200867	H-Bend 200x200	9	
10	WG0016	200895	Straight L=2779,5	36	1,
11	WG0017	200898	Straight L=2929,5	2	1,
12	WG0018	200901	Straight L=473,2	18	
13		200910	Straight L=976,5	1	
14		200919	Straight L=320,3	1	
15		200925	Straight L=1119,8	1	
16		200942	E-Bend 150° 120x120	1	1,
17		201148	Straight L=2641,1	1	1,
18		201151	Straight L=2241	1	1,
19		201227	Straight L=695	1	
20		201230	Straight L=1681,5	1	

Subtotal	194
Administration Fee and Others	
TOTAL COST (EURO, DDP)	194

Authorized: *Jianbing Zhao*

Jian-Bing ZHAO
Division of Technology Development
Institute of High Energy Physics, CAS
No. 19B, Yuquan Road, Beijing, 100049, China
Tel: 86 10 8823 6935 Fax: 86 10 8823 3101
E-mail: zhaobj@ihep.ac.cn

中国科学院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences

Quotation for Waveguide Components for MAX IV (Updated Nov.20, 2012)

Price: CIF

ITEM	Components
1	Phase shifter & Variable Attenuator
2	RF window
3	SiC High Power Dummy Load
	Administration Fee and Others
	Total (CIF, EUR)

Note: The price includes the transport

Scope of work: Design, fabrication, t

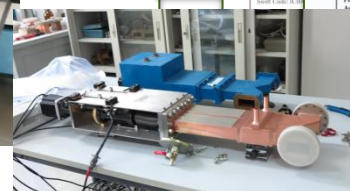
Delivery: Within 6 months after orde

Payment: 100% TT within 30days af

Authorized: *Jianbing Zhao*

Jian-bing ZHAO
Dept. of Technology Development
Institute of High Energy Physics, CA

ITEM	Componer
200883	Straight section: L=165
202570	Straight section: L=531
200938	H-bend 90° L=200mm;
200934	E-bend 90° L=200mm;
200867	H-bend 90° L=200mm;
200969	H-bend 30° L=95.4mm
202407	Straight section: L=300
	Administration Fee and Others
	Total (CIF, EUR)



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INVOICE No. 2012H-EP-M001
(发票)

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INVOICE No. 2012H-EP-M006
(发票)

PACKING LIST No. 2012H-EP-M006 (装箱单)					
Invoice No. 2012H-EP-M006 Date: November 06, 2012					
To: MAX-Lab, Lund University Ole Rosner, s.k. SE-22100, Lund, Sweden Attn: Ole's Kambaro Tel: +46 90 222 87 45					
From: Beijing, China To: Lund, Sweden Via: 中国北京 瑞典 荷马德					
Item	Discussions	Quantity	N/W	G/W	Measurement
1	2009018 E-bend Waveguide	58 sets	382 kg	499 kg	11 boxes
2	2009018 Straight Waveguide	43 sets	409 kg	622 kg	MM
	加速波部件-波导管				1130x320x420mm 990x990x420mm 1260x990x420mm 1260x1030x420mm 1460x320x420mm 2x1460x800x420mm 2x1460x800x420mm 1510x700x420mm 1440x740x420mm
Total Weight			811 kg	1321 kg	

MAX IV: Klystron gallery & Linac tunnel



Klystron gallery
June → September
2013



Linac tunnel
June → September
2013





Thank you for your attention!!