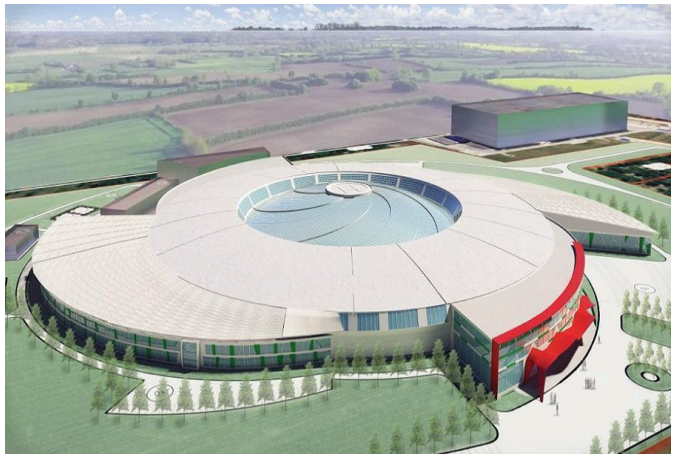
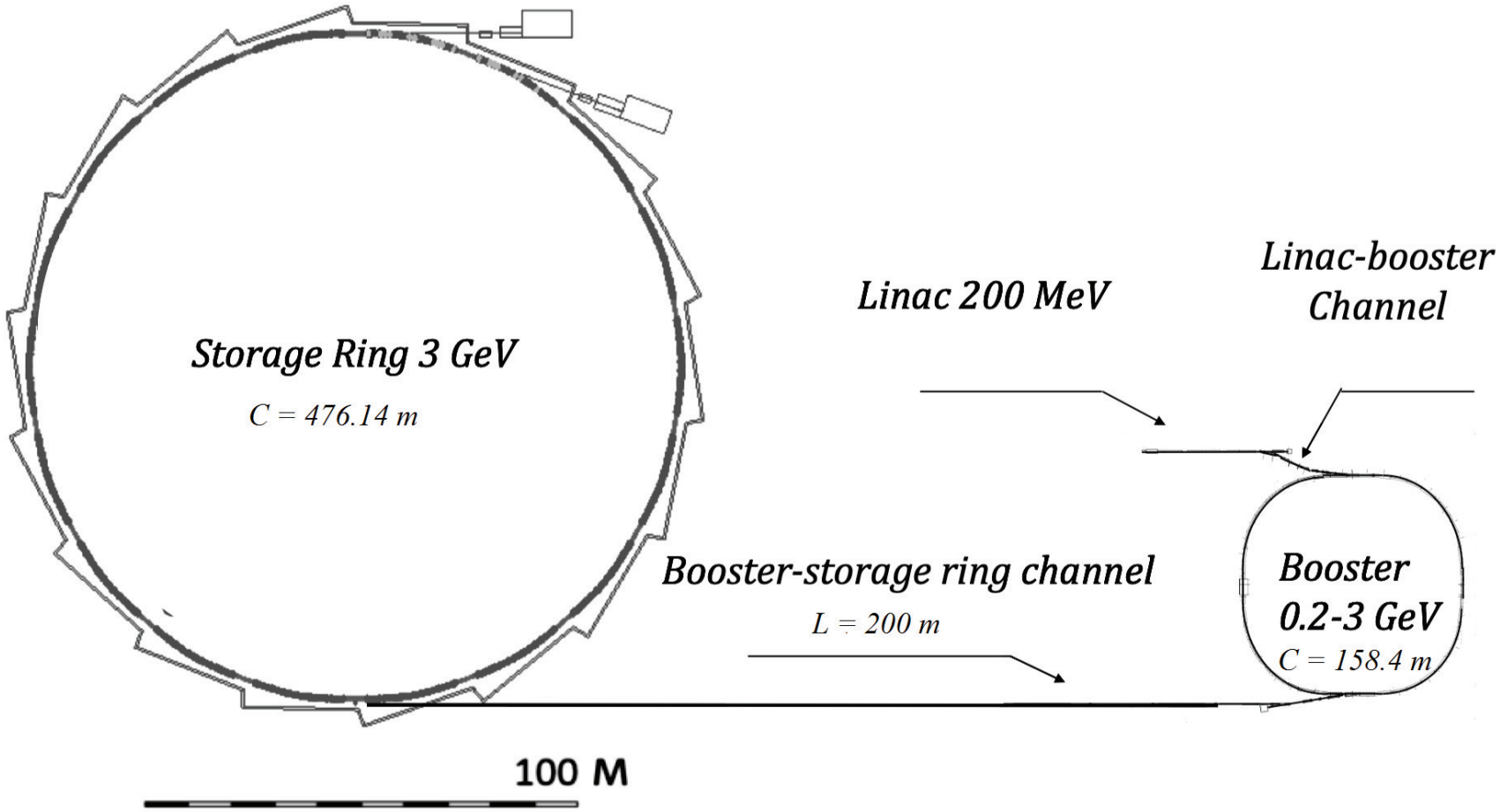
200 MeV linac development for the SKIF light source



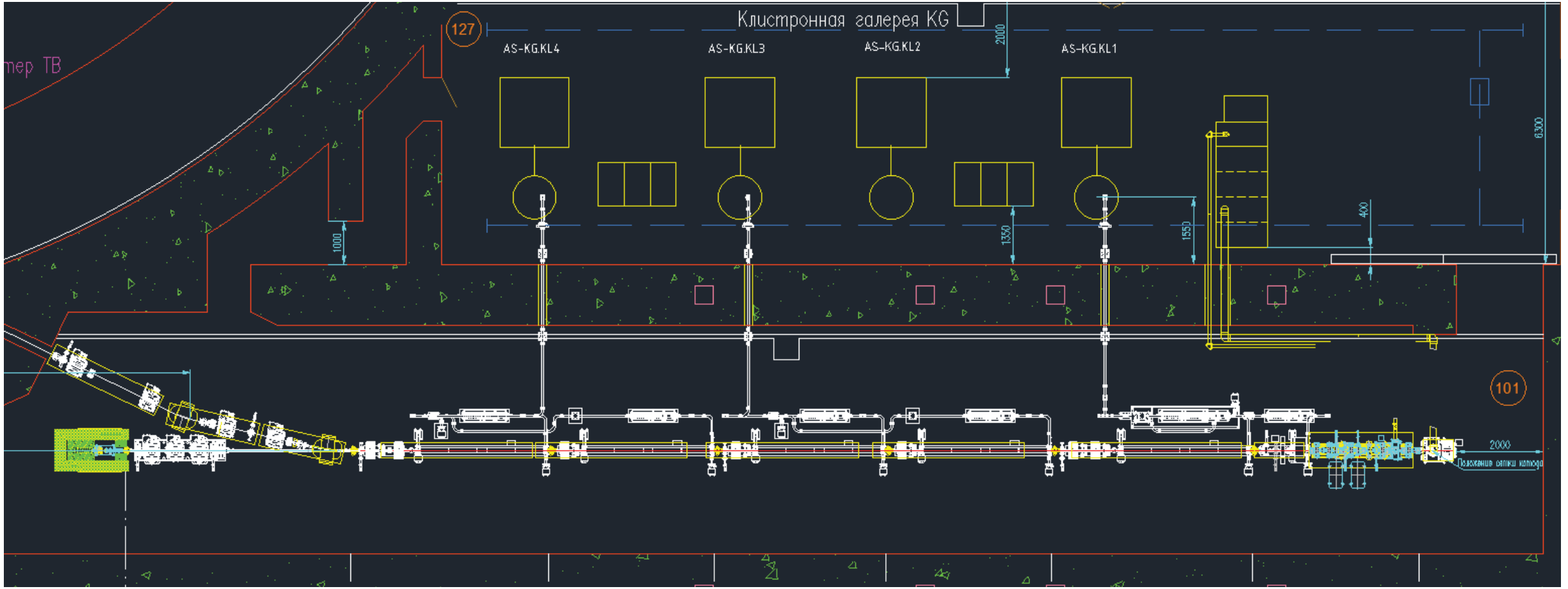
Mariya Arsentyeva

Budker institute of nuclear physics

SKIF light source



SKIF linear accelerator



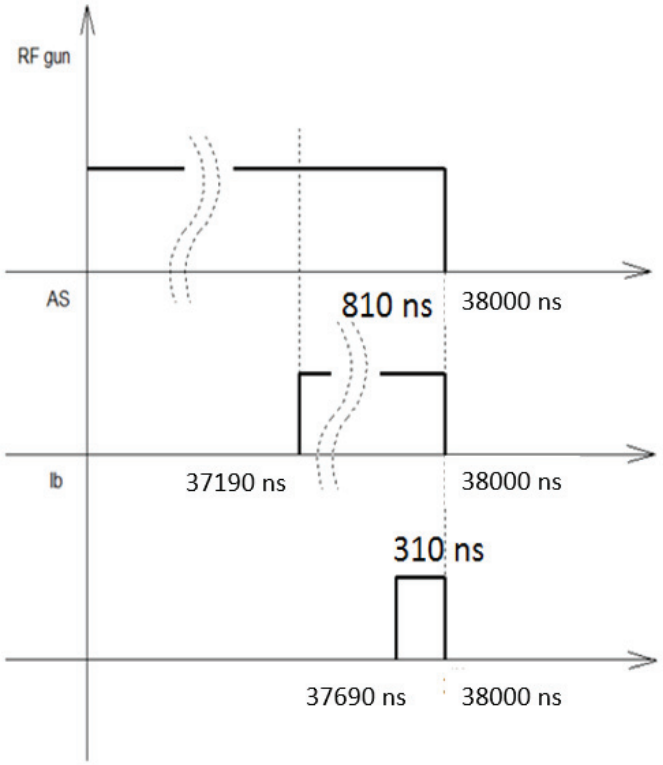
SKIF linear accelerator

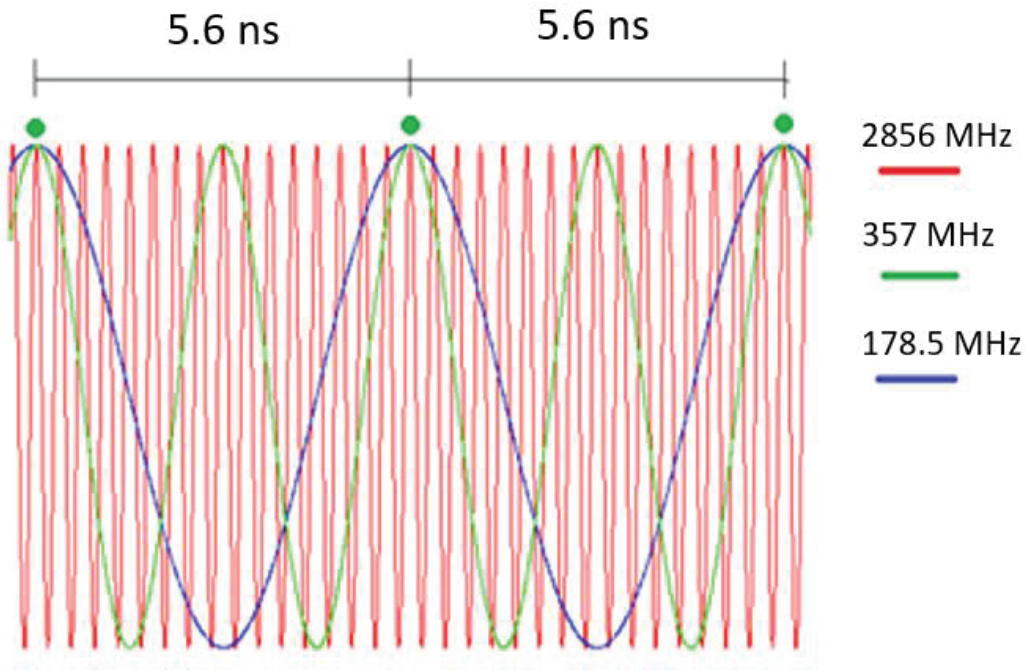
Energy	200 MeV
Energy spread at 200 MeV	1% (RMS)
Injection frequency	1 Hz
Bunch period	5.6 ns
Beam duration	~300 ns
Bunch number	55
Single bunch charge	0.3 nC
Full beam charge	16.5 nC
Horizontal emittance at 200 MeV	150 nm

Outline

- RF power sources: klystrons
- RF electron gun
- Bunching system
- Accelerating structures
- Magnet system
- Diagnostics
- Waveguide system
- Accelerated beam parameters

Temporal diagram





- RF gun current pulse
- Pulse of the maximum duration current at the accelerating structure
- Beam current pulse

2856 MHz signal – regular accelerating structure voltage
357 MHz signal – voltage of the booster synchrotron cavity
178.5 signal – RF gun voltage
(Green points indicates electron bunches)

*RF control system to be developed by Libera

Outline

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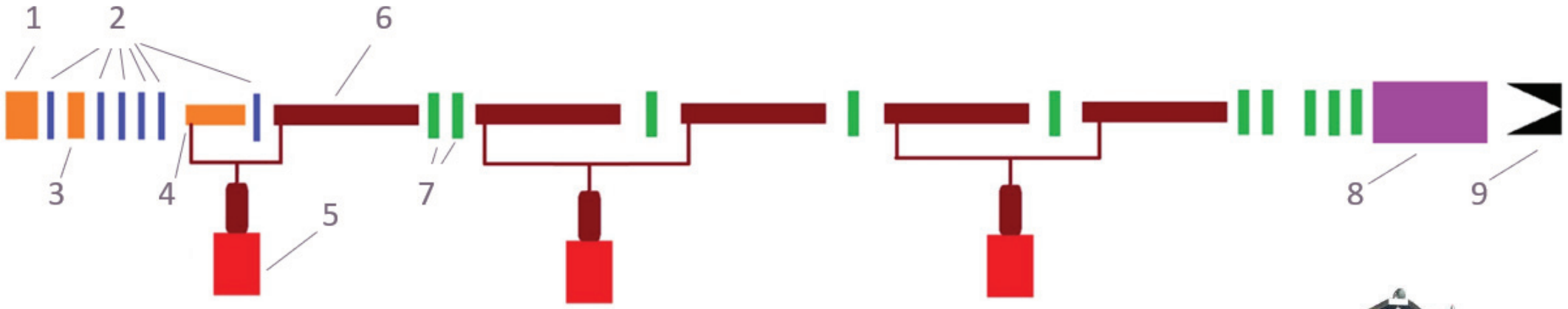
RF power sources: klystrons



Layout of the linac: 1 – electron gun, 2 – solenoids,
3 – 535 MHz buncher, 4 – preaccelerator, 5 – klystrons,
6 – regular accelerating structures, 7 – quadruple lenses,
8 – spectrometer, 9 – Faraday cup

Название	**Canon E3730A**
Общее число клистронов	3
Частота	2855-2856 МГц
Высокое напряжение	350 кВ
Ток пучка	400 А
Входная СВЧ мощность	500 Вт
Выходная СВЧ мощность	≥ 50 МВт
Выходная средняя мощность	10 кВт

Outline

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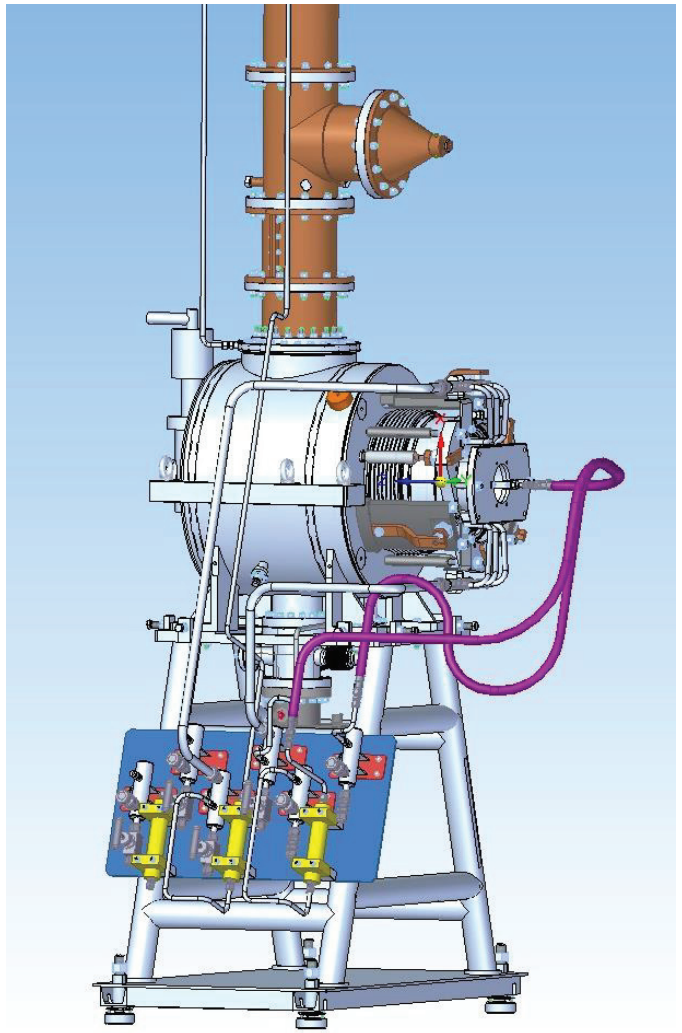
RF electron gun



RF gun

Operating frequency	178.5 MHz
Electric field amplitude	13 MV/m
Quality factor	10300
Pulse power	500 kW

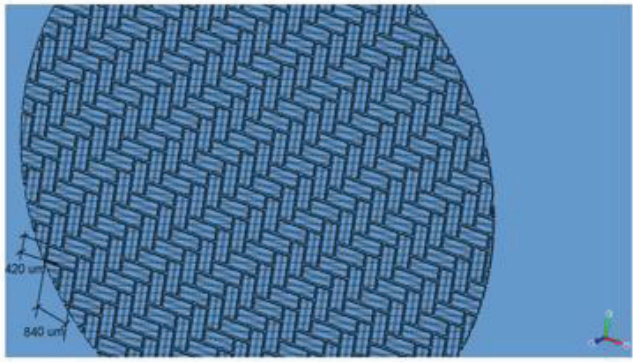
RF gun is based on the cathode-grid assembly of the RF triode together with the cathode current modulator. Thus, one can vary charge of the beam being injected.

Operating frequency	176-180 MHz
Output power	700 kW (<100 mcs)
Input power	10 mW
Amplification	78.5 dB
Cooling	Air
Power	<300 W (at the pulse frequency < 1Hz)

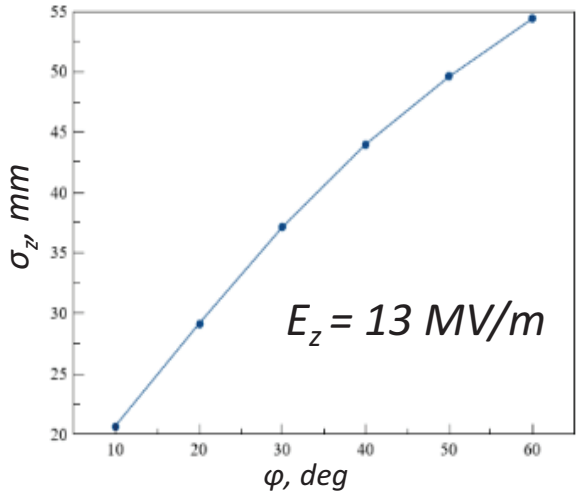
Specifications of the RF gun generator (Triada TV)

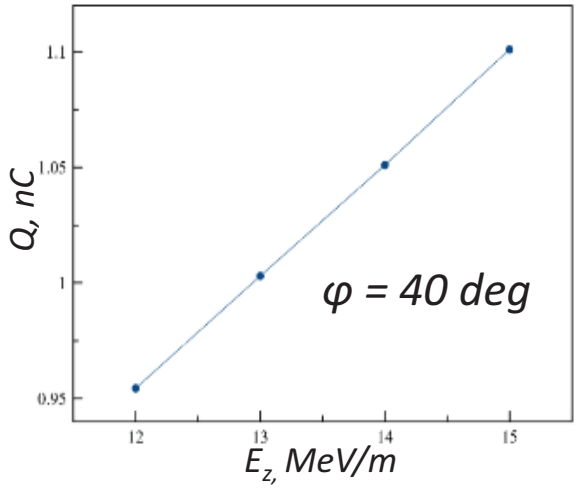
RF electron gun: cathode-grid assembly of the RF triode

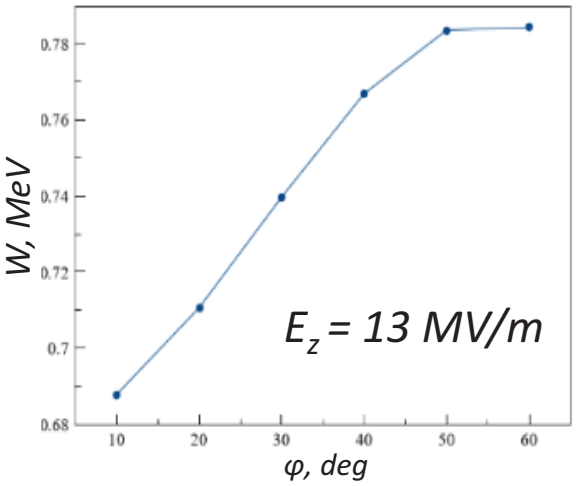
Grid of the triode

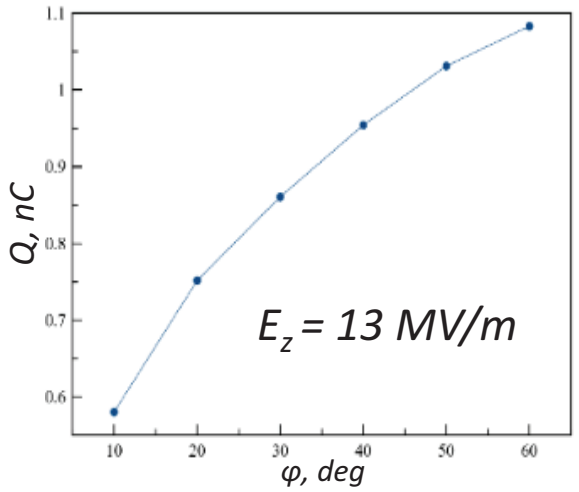


Dissipated power at the grid	3 W
Heater voltage	12 V
Heater current	1 A
Bias voltage	–150÷0 V
Maximum cathode peak current	11 A
Grid peak current	4 A
Pulse duration	10 mcs
Minimal duty cycle	1000
Grid transparency	75%
Coefficient of the electric field penetration	26%









Outline

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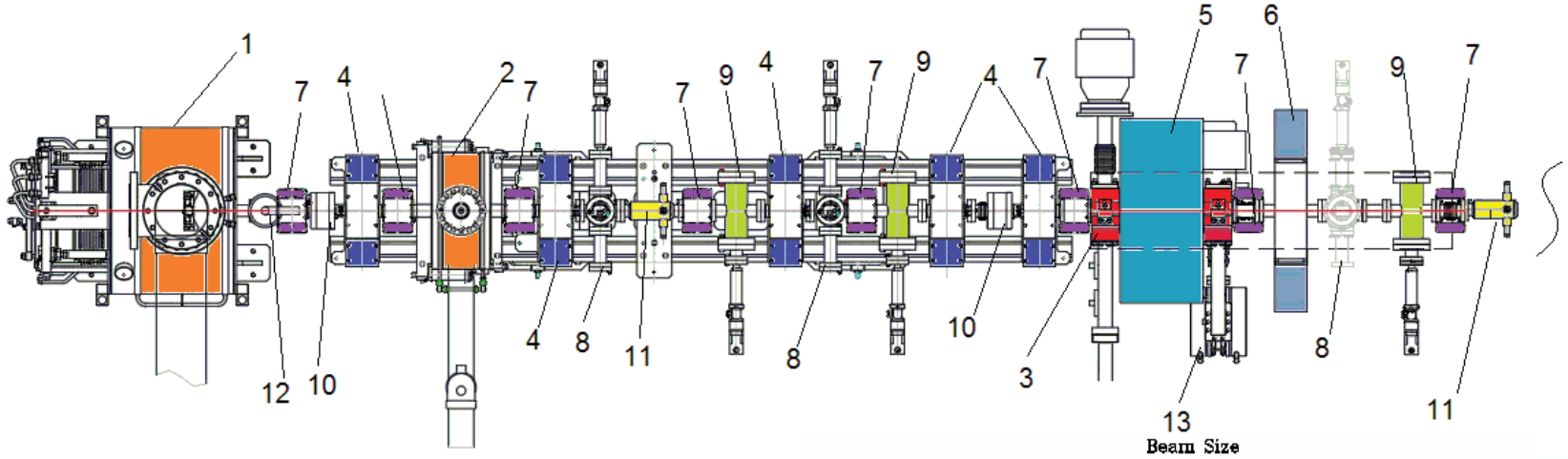
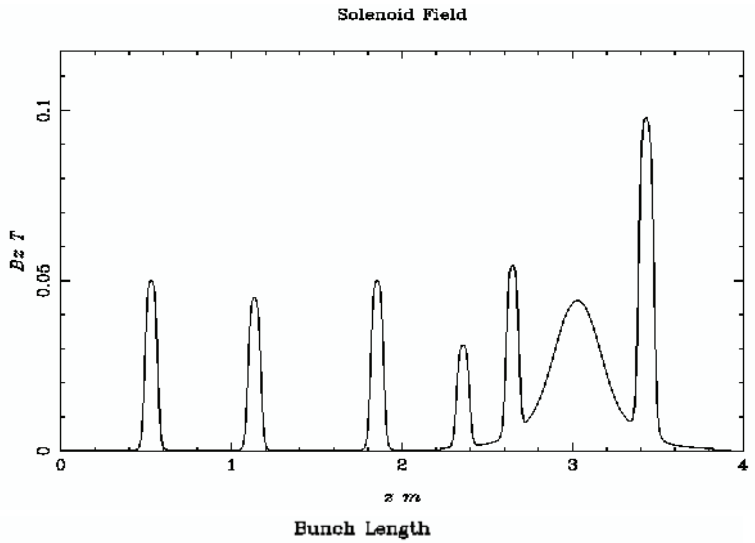
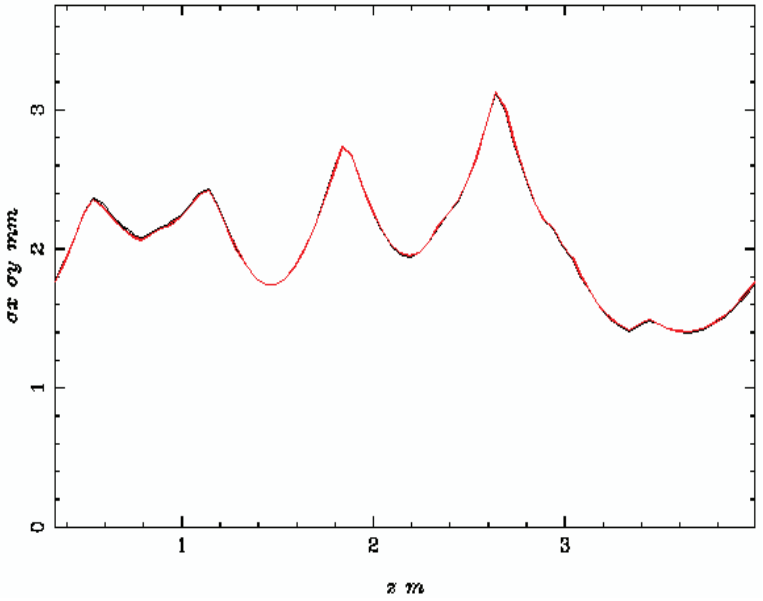
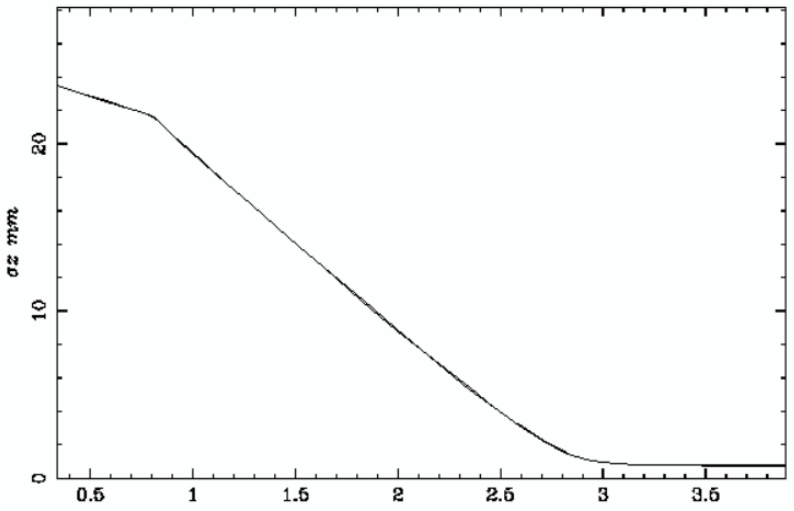
Bunching system





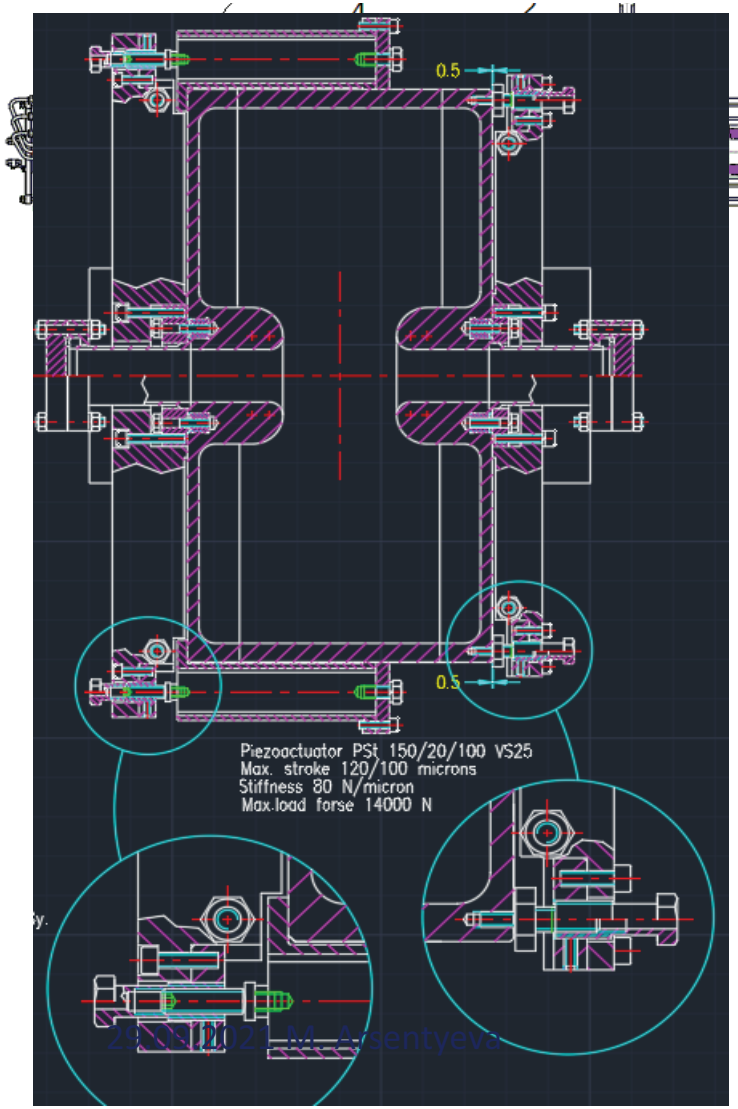
1 – 178.5 MHz RF gun, 2 – 535.5 MHz third harmonic cavity, 3 – preaccelerator, 4 – solenoids of the bunching channel, 5 – preaccelerator solenoids, 6 – matching solenoid, 7 – dipole correctors, 8 – fluorescent screens, 9 – Cherenkov sensors, 10 – FCTs, 11 – BPMs, 12 – automatic vacuum valve, 13 – RF loading

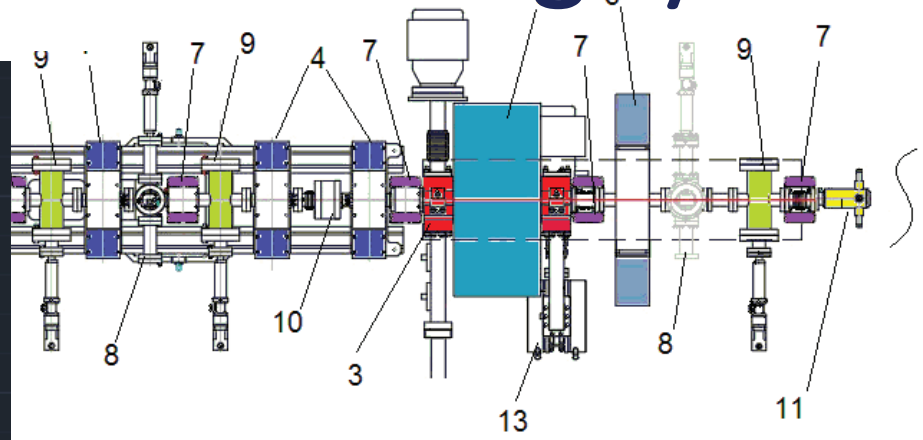




Bunching system

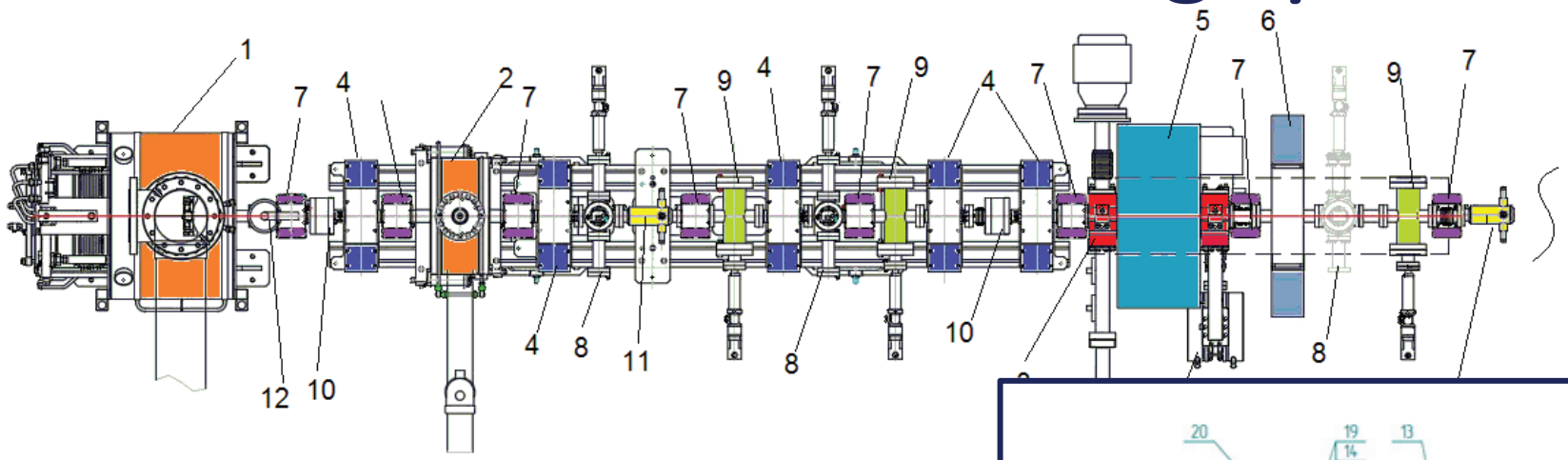
Third harmonic cavity



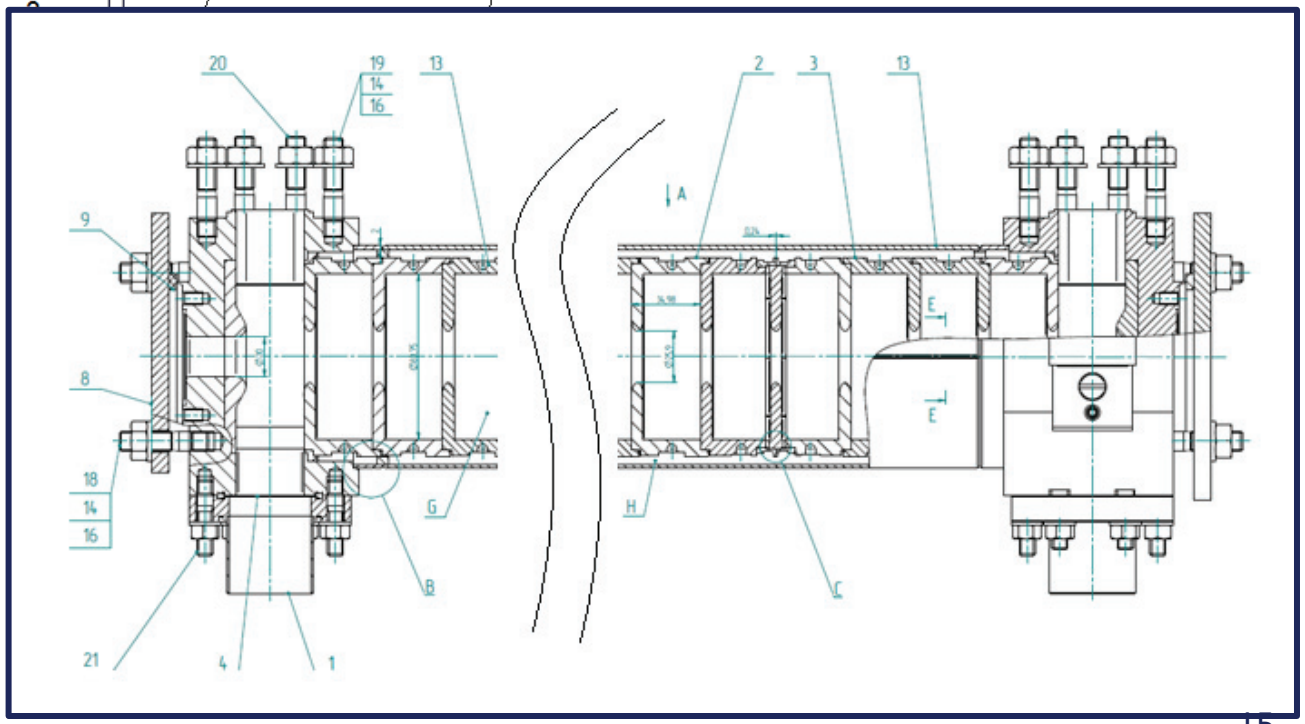


Operating frequency	535.3-535.5 MHz
Quality factor	20210
Effective impedance	148.2 Ohm
TTF	0.9614564
Stored RF energy	0.036267
Effective voltage	0.19 MV
Maximum wall dissip. power	6.02 kW
Average wall dissip. power	<1.5 W

Bunching system



Preaccelerator



Outline

- RF power sources: klystrons
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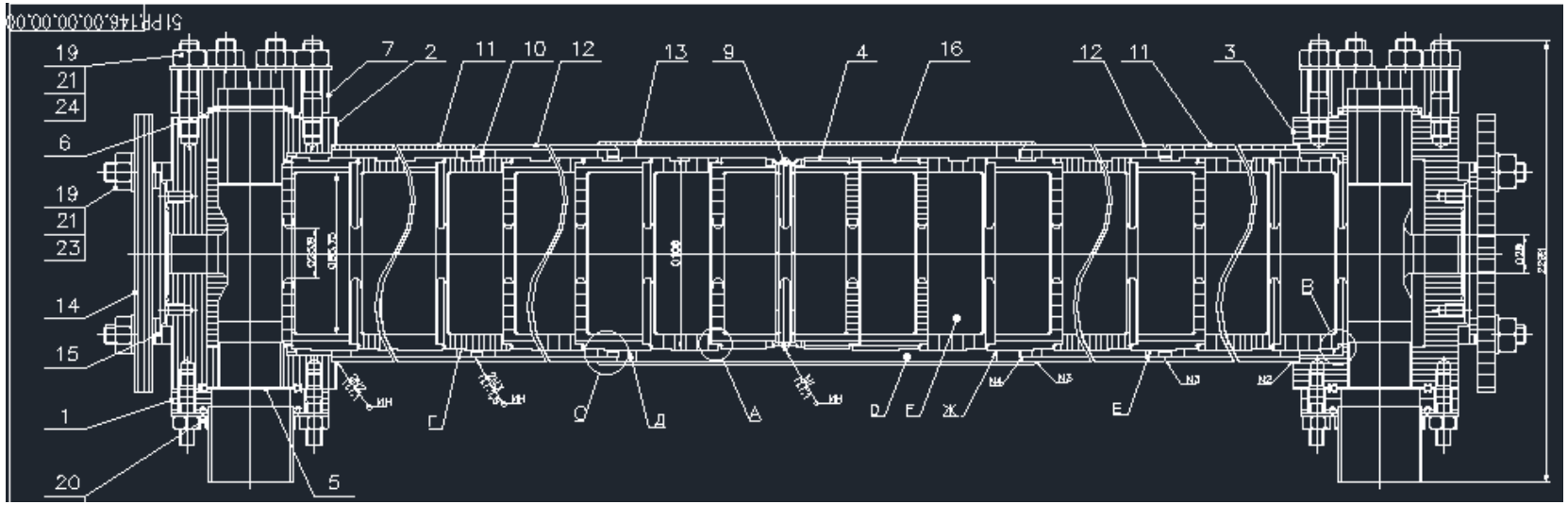
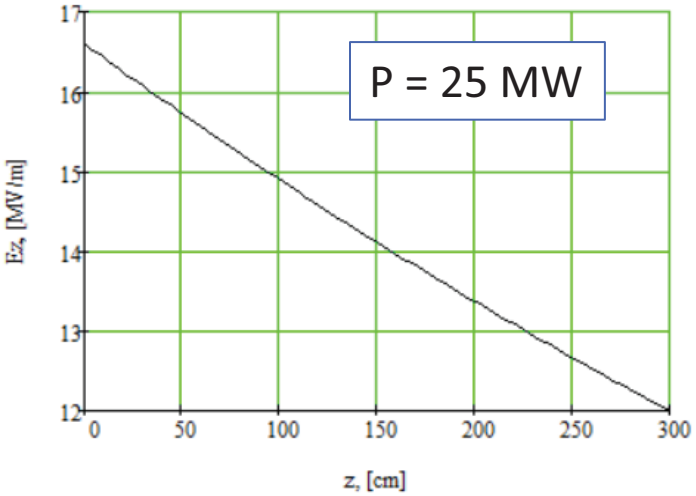
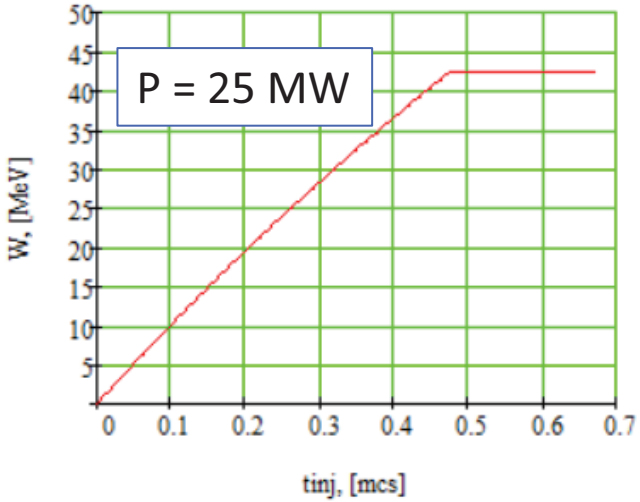
Accelerating structures



Disk loaded traveling wave accelerating structure operating at the 2π/3 mode

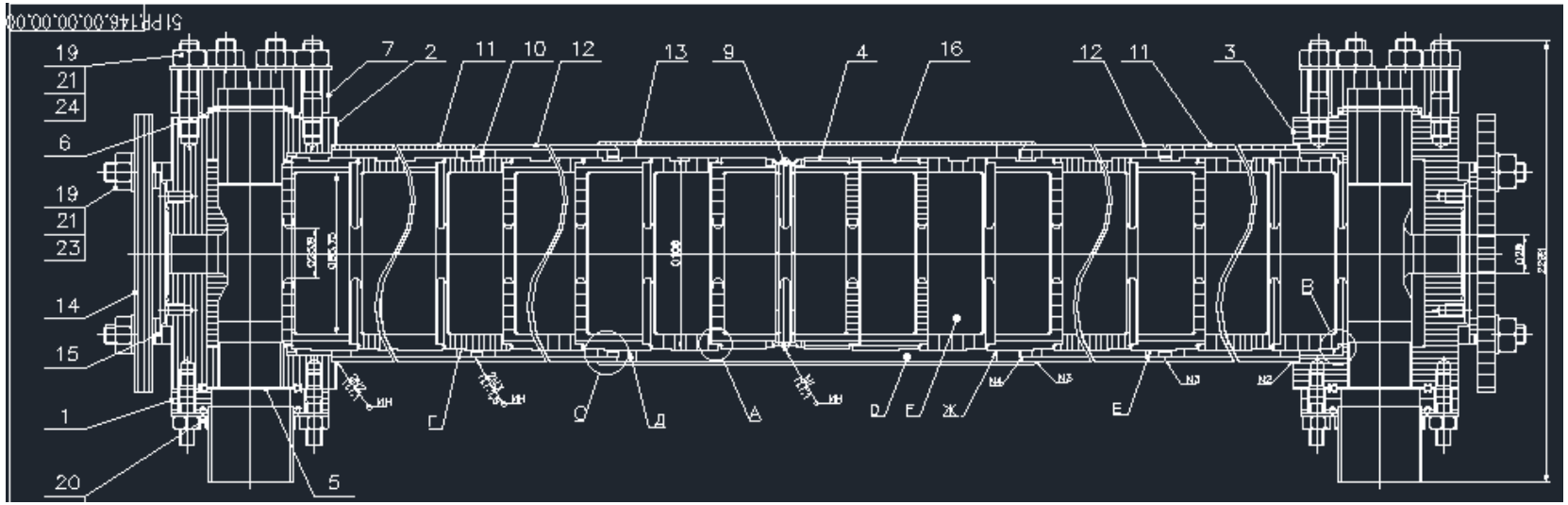
Operating frequency	2856 MHz
Quality factor	13000
Period	34.99 mm
Cell diameter	83.75 mm
Diaphragm thickness	6 mm
Length	2.93 m
Shunt impedance	51 Ohm/m
Phase velocity	*c*
Group velocity	0.021 *c*
Filling time	0.456 mcs





~50 MeV in the 1st accelerating structure (input power 40 MW)
~40 MeV in the 2nd-5th accelerating structures (input power 25 MW)

Accelerating structures



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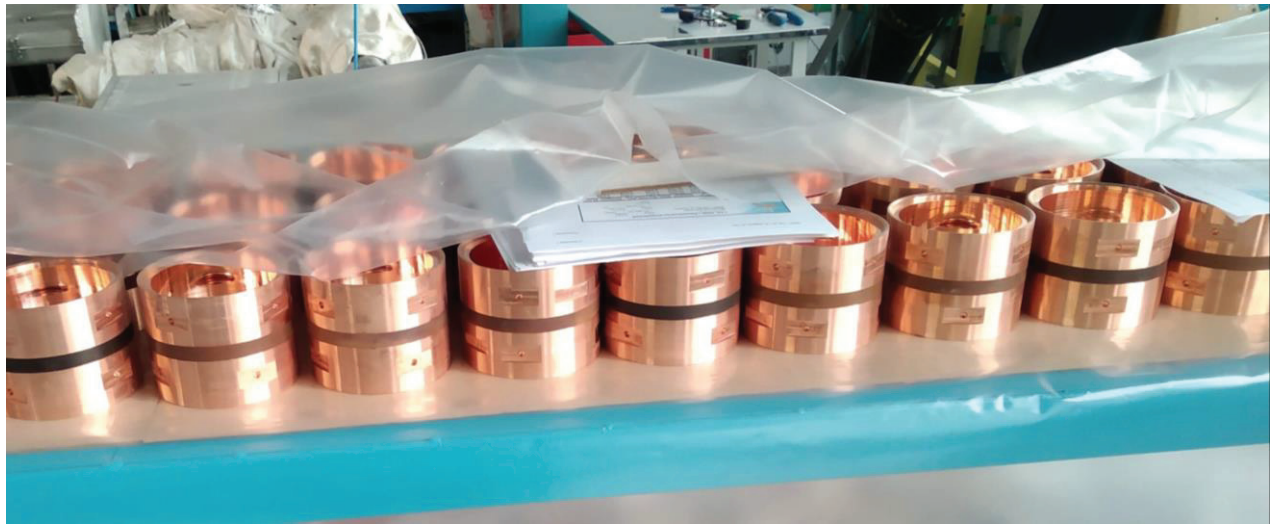

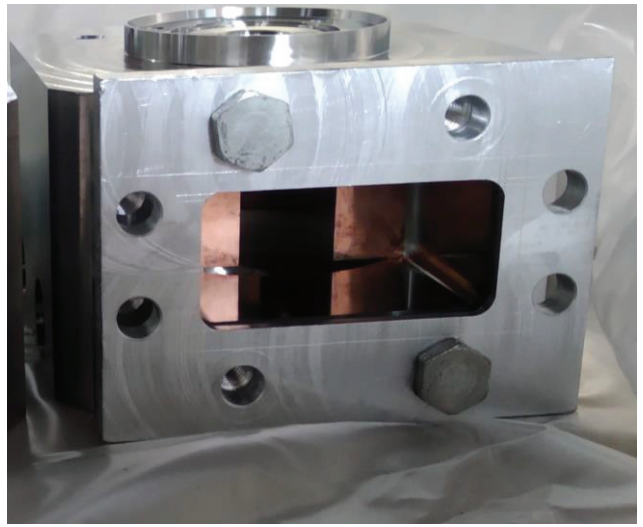

Outline

- RF power sources: klystrons
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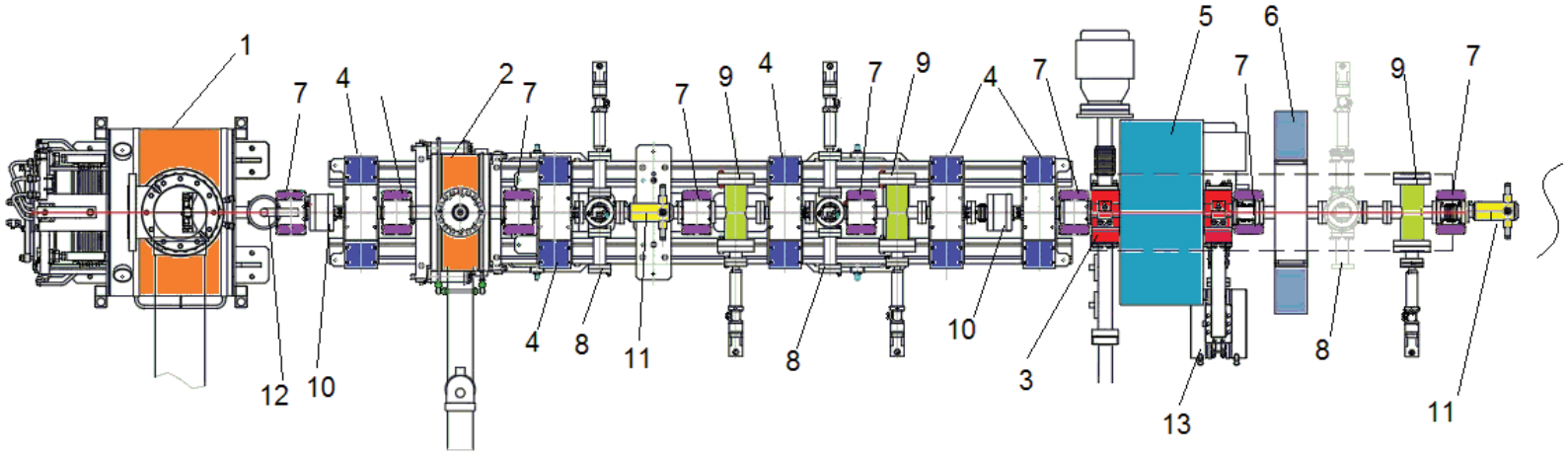
Magnet system



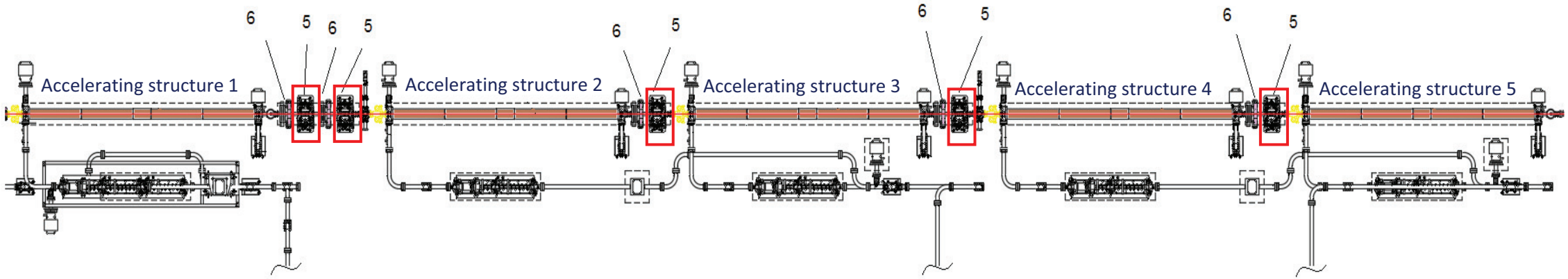
- 5 solenoids in the bunching channel, 2 preaccelerator solenoids, matching solenoid

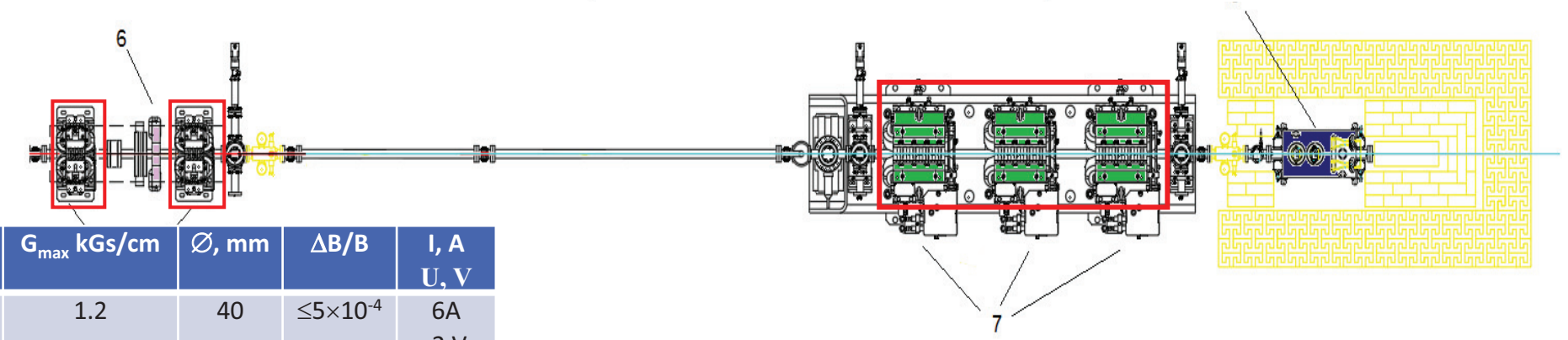
1 – 178.5 MHz RF gun, 2 – 535.5 MHz third harmonic cavity, 3 – preaccelerator, 4 – solenoids of the bunching channel, 5 – preaccelerator solenoids, 6 – matching solenoid, 7 – dipole correctors, 8 – fluorescent screens, 9 – Cherenkov sensors, 10 – FCTs, 11 – BPMs, 12 – automatic vacuum valve, 13 – RF loading

Magnet	Qty	L, mm	B_{max}, kGs	∅, mm	ΔB/B	I, A; U, V
Bunching channel solenoid	5	100	0.65	37	$\leq 10^{-3}$	5A 10 V
Preaccelerator solenoid	2	250	1.0	120	$\leq 10^{-3}$	300 A 5 V
Matching solenoid	1	100	1.5	37	$\leq 5\times10^{-4}$	5 A 10 V

Magnet system

- 7 quadruple lenses in the regular linac part, 3 quadruple lenses in the diagnostic channel

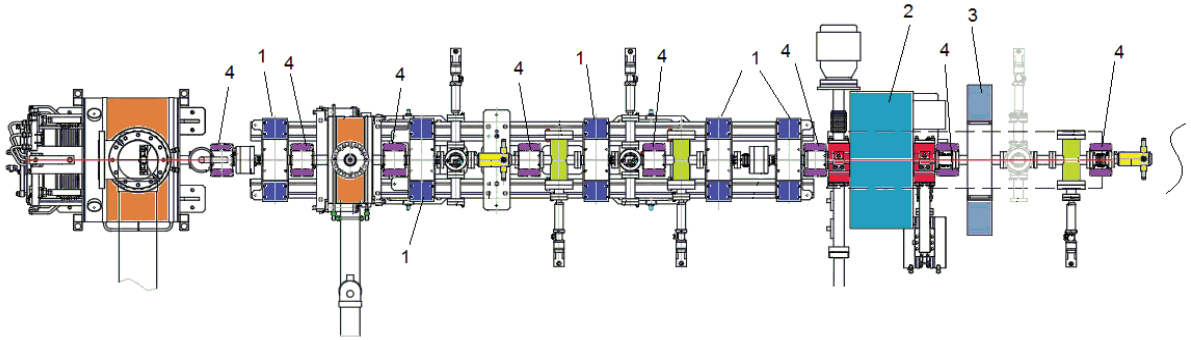


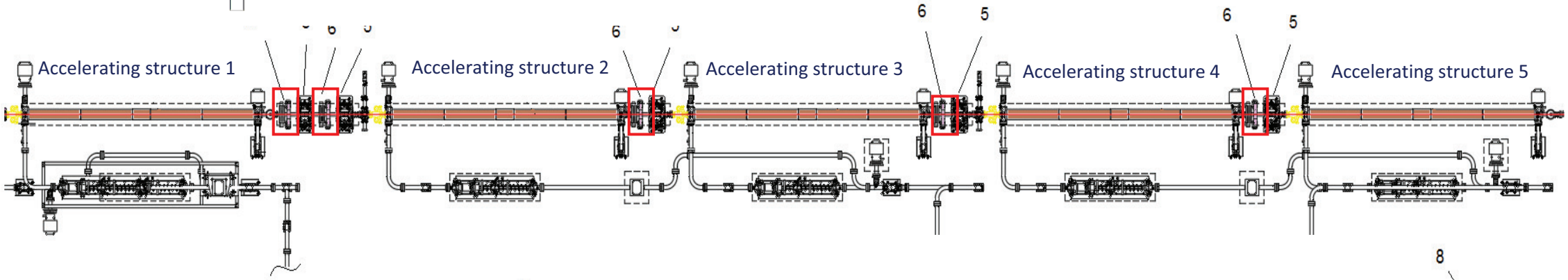


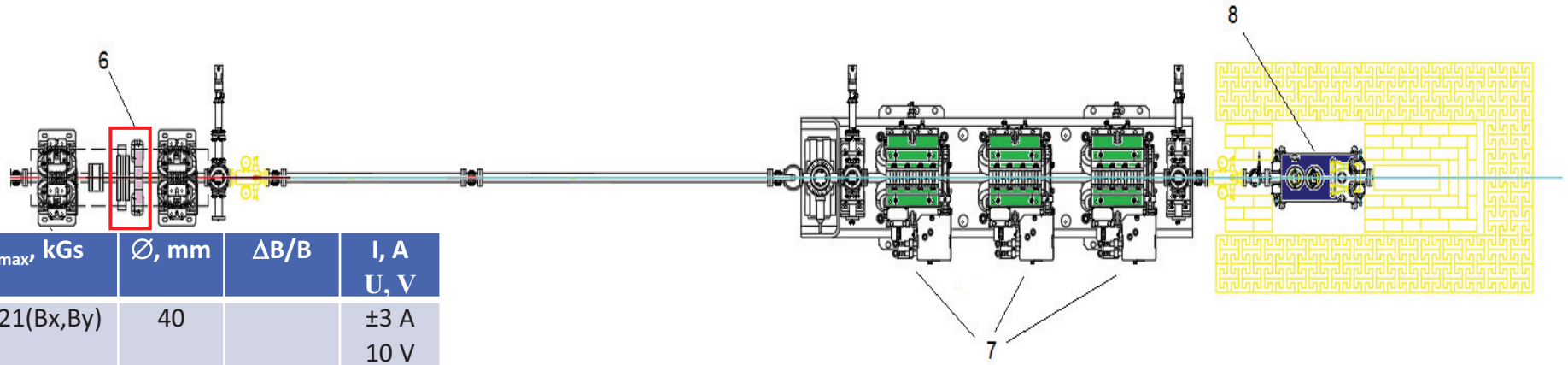
Magnet	Qty	L, mm	G_{max} kGs/cm	∅, mm	ΔB/B	I, A U, V
Quadruple lenses in the regular linac	7	100	1.2	40	$\leq 5\times10^{-4}$	6A 2 V
Quadruple lenses in the diagnostic channel	3	150	1.2	40	$\leq 5\times10^{-4}$	40 A 1.5 V

Magnet system

- 14 two-dimensional dipole correctors







Magnet	Qty	L, mm	B_{max}, kGs	∅, mm	ΔB/B	I, A U, V
Bunching channel correctors	8	70	0.021(Bx,By)	40		±3 A 10 V
Regular linac correctors	6	70	0.5 (Bx, By)	40		±6 A 2 V

Outline

- RF power sources: klystrons
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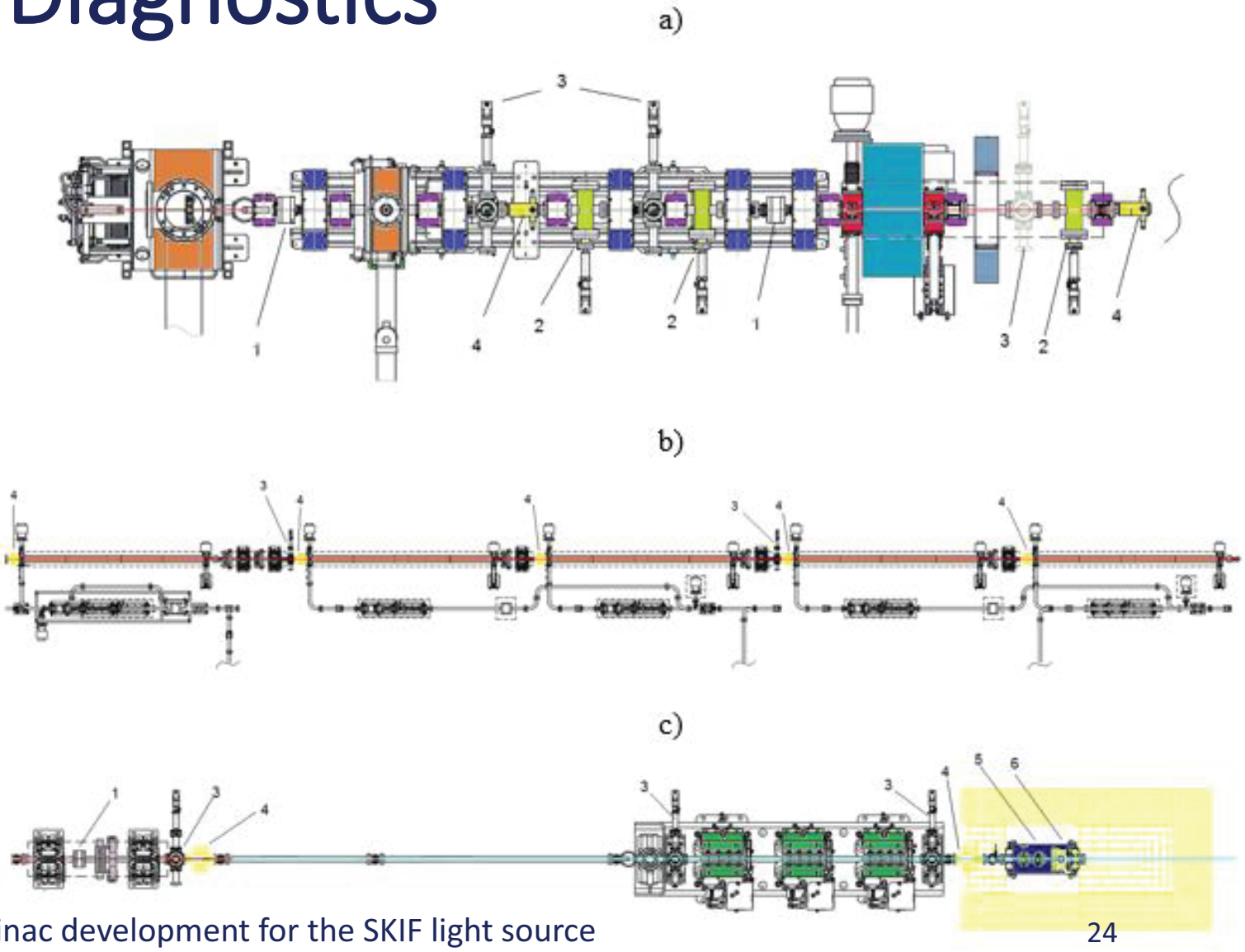
Diagnostics

- 3 FCTs
- 8 fluorescent screens
- 3 ЧCherenkov sensors
- 7 BPMs
- Magnet spectrometer
- Faraday cup



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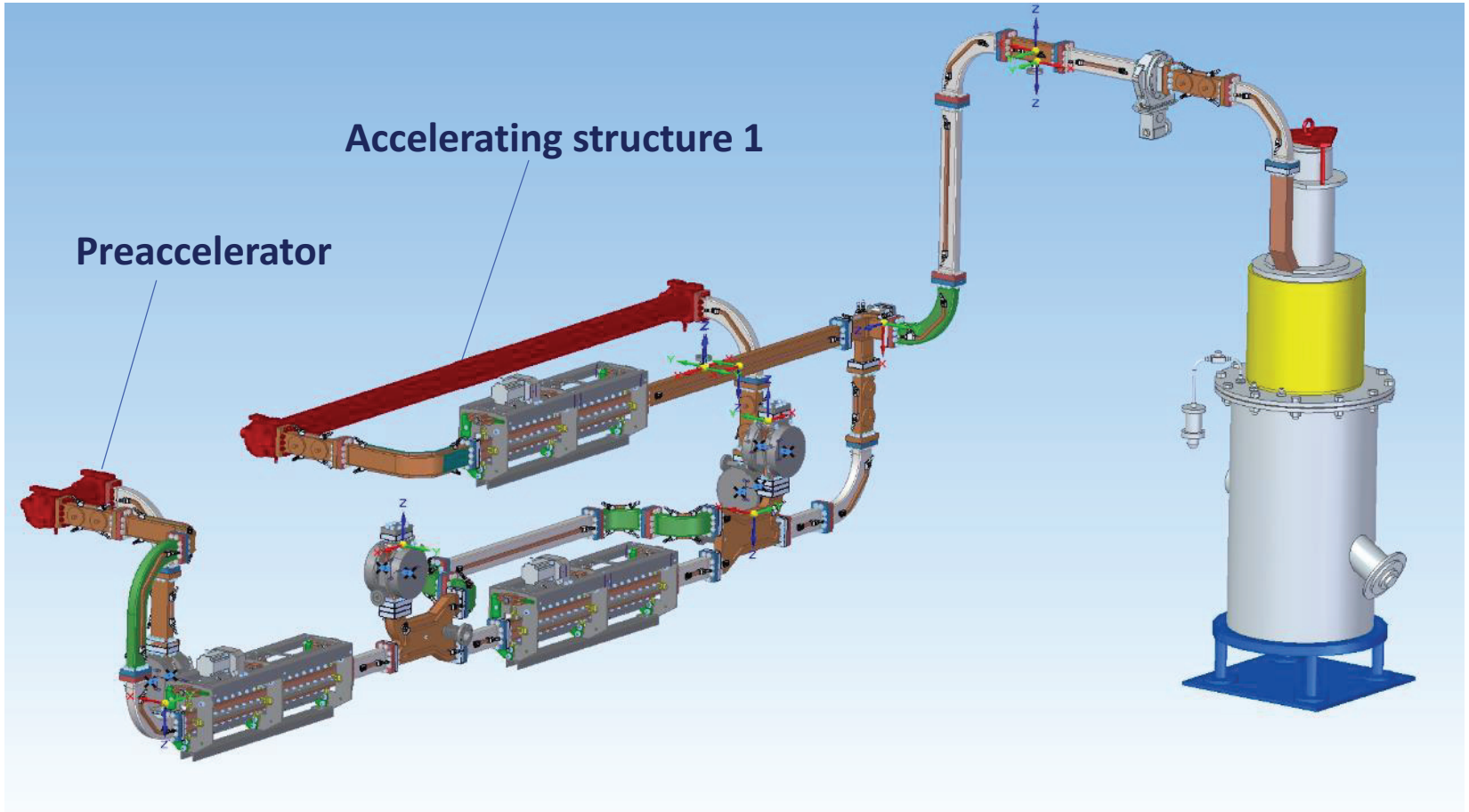
Waveguide system

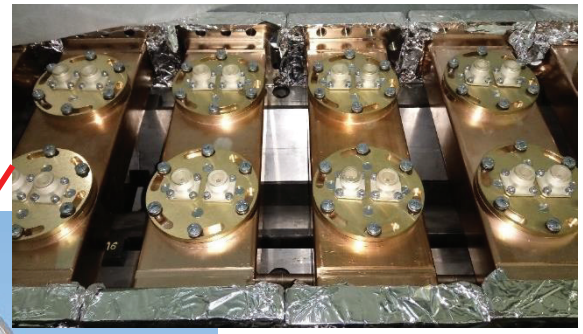


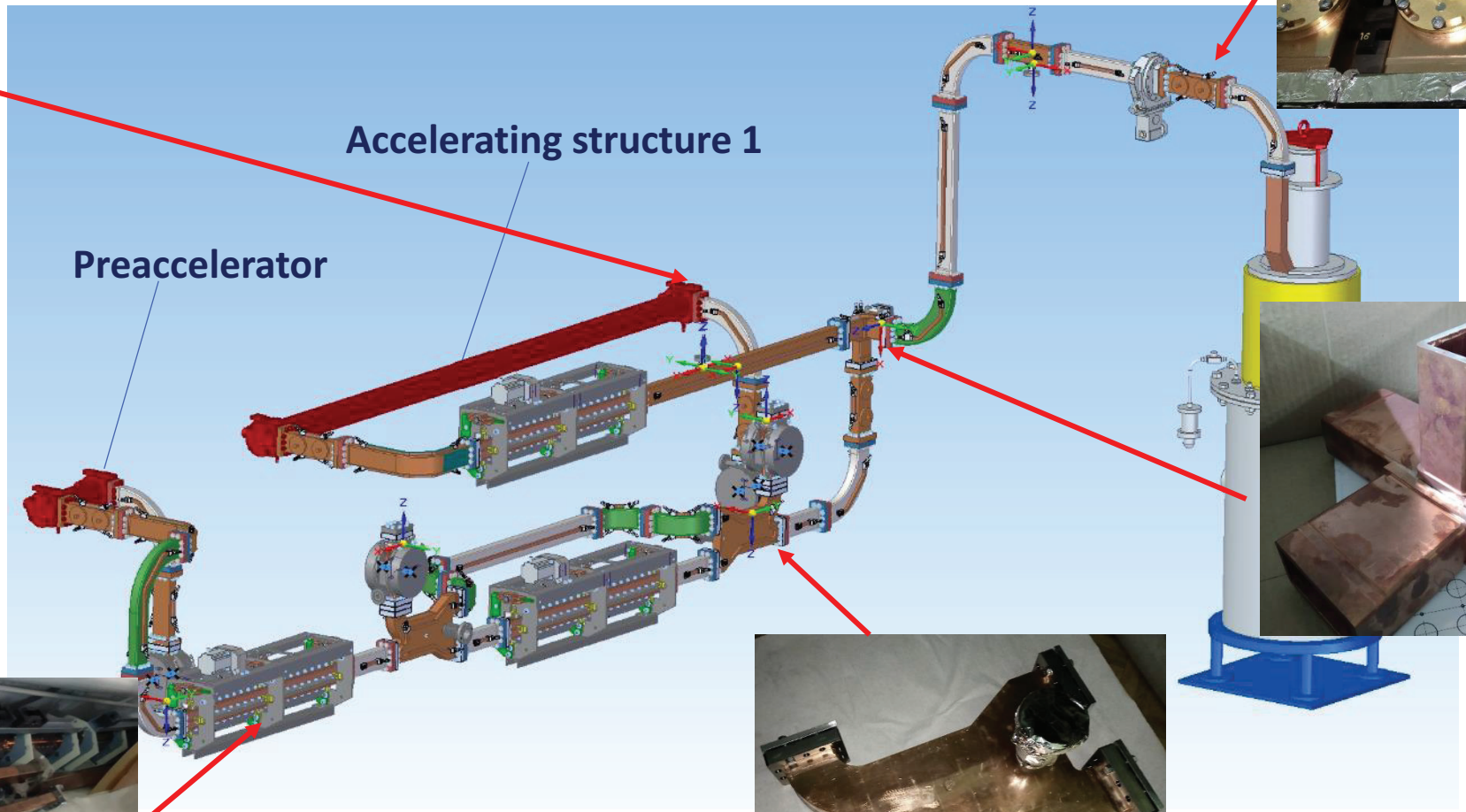
Waveguide system scheme for the 1st klystron

Waveguide system

RF load

Meas. couplers





7 dB coupler

Phase shifter

3 dB coupler

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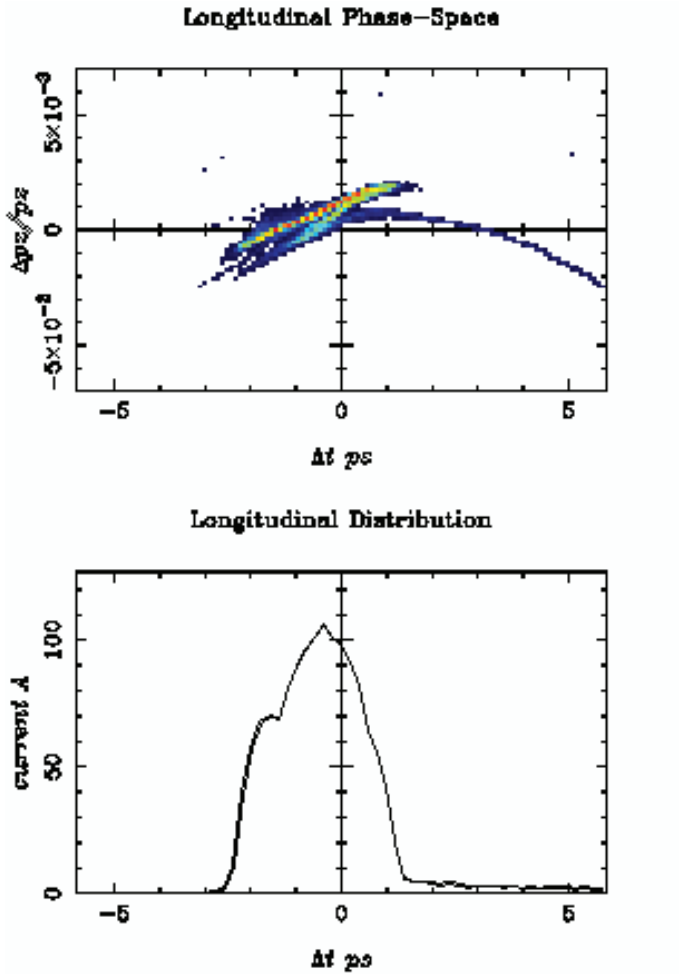
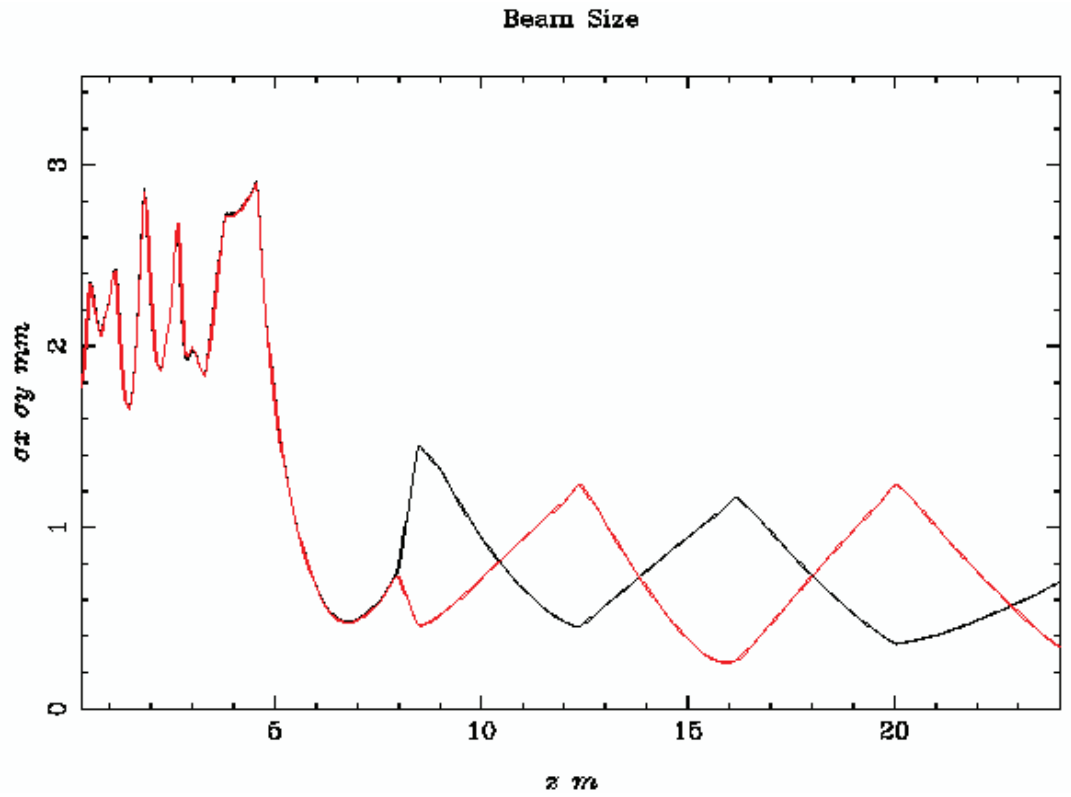
Accelerated beam parameters

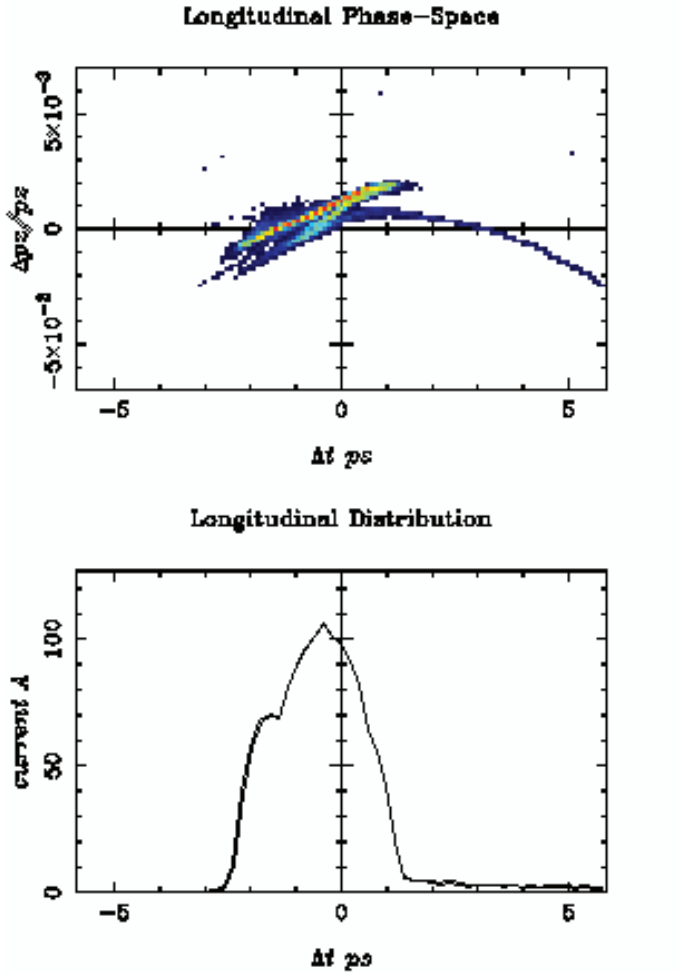


Longitudinal beam profile



RMS beam size

Accelerated beam parameters



Longitudinal beam profile

Energy	200 MeV
Energy spread (RMS)	0.3%
Horizontal emittance	50 nm
Single bunch charge	0.3 nC

Acknowledgements

The author is grateful for the assistance and the information provided to V. Volkov, O. Meshkov, D. Nikiforov, S. Karnaev, A. Batrakov, A. Starostenko, A. Barnyakov, A. Levichev, A. Andrianov, V. Chekodov, N. Vasileva, S. Shiyankov, O. Pavlov, S. Samoylov etc.