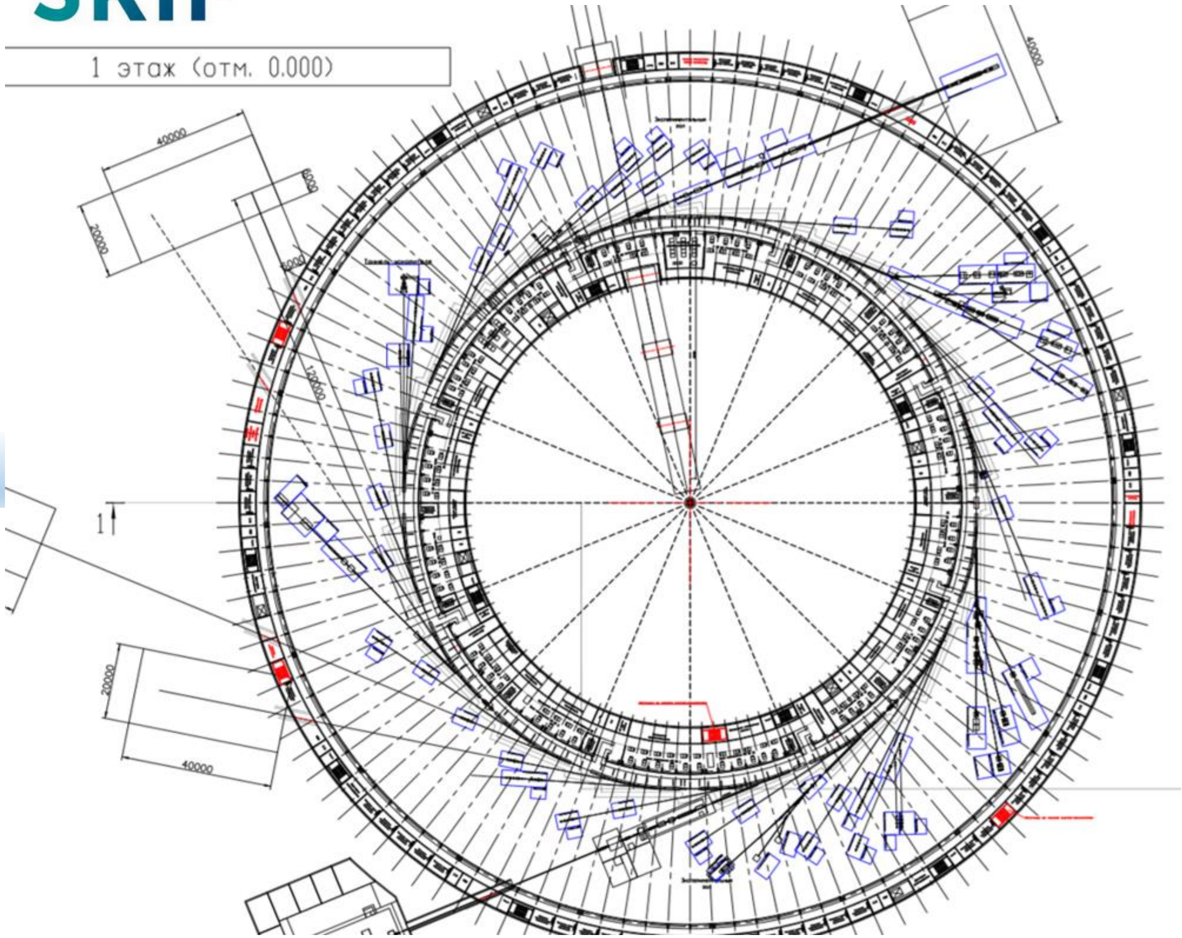


Novosibirsk fourth generation light source SKIF

E. Levichev (on behalf of the SKIF team)

Boreskov Institute of Catalysis/Budker Institute of Nuclear Physics

Novosibirsk, Russia

AFAD-2021, 16-18 March 2021

SKIF (Rus.acr.: Siberian Circular Photon Source)

Russian acronym SKIF (Siberian Circular Photon Source) also means Scyth or Scythian. Scythians were ancient nomads originally located in northern Black Sea and fore-Caucasus regions.

Scytho-Siberian culture attributes to the population inhabited modern Altai Republic (south of Novosibirsk), which were known as skilled crafts gold workers. Altai kurgans – large burial mounds – provides many samples of beautiful gold works, and we believe that our new synchrotron light source will shine as bright as Scythian jewelries.

History

1.	V.Putin supports new forth gen. light source in Novosibirsk	Feb 2018
2.	The land for SKIF in Kol’tsovo was assigned to Institute of Catalysis (IC)	Apr 2019
3.	Russian Government allocates SKIF budget to IC	Dec 2019
4.	Building and civil engineering design company is selected	Mar 2020
5.	Contract for civil engineering design is signed	Apr 2020
6.	IC is assigned as a public contracting authority	Sep 2020
7.	Contract for the injector and booster between IC and BINP is signed	Nov 2020
8.	Civil engineering design is finished	Dec 2020
9.	Constructing company is selected	Feb 2021
10.	Contract with construction company	≈May 2021
11.	Contract with BINP for the rest of the SKIF	≈May 2021
12.	Land preparation start	≈May 2021
13.	Groundbreaking	≈Nov 2021
14.	**First beam in SKIF**	**Dec 2023**
15.	**First six experimental stations**	**Dec 2024**

Why Novosibirsk?

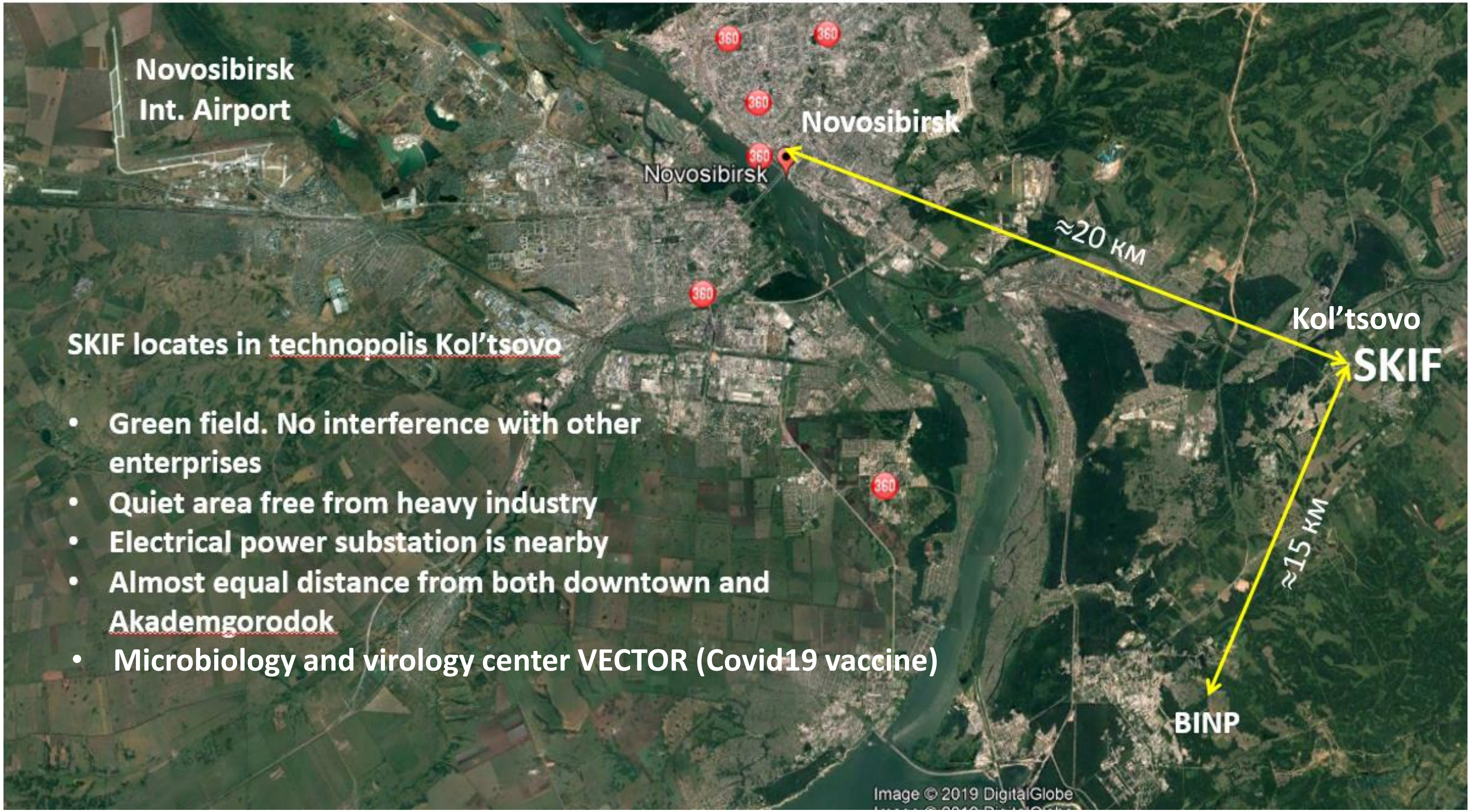
- Novosibirsk Akademgorodok (Academic city) consolidates more than 40 research institutes in physics, chemistry, biology, medicine, condensed matter, geology, etc. and most of them have expressed their interest in new facility
- BINP has great experience in development, production, study and maintenance of large accelerator facilities including synchrotron light sources
- Siberian Synchrotron and Terahertz Radiation Center consists of several dozen of research groups with more than 40 years of experimental experience
- Novosibirsk State University and Novosibirsk Technical State University will secure new scientific center with young but skilled staff


Institutes of Akademgotrodok


Novosibirsk State University


Novosibirsk Technical State University

Why Kol’tsovo?



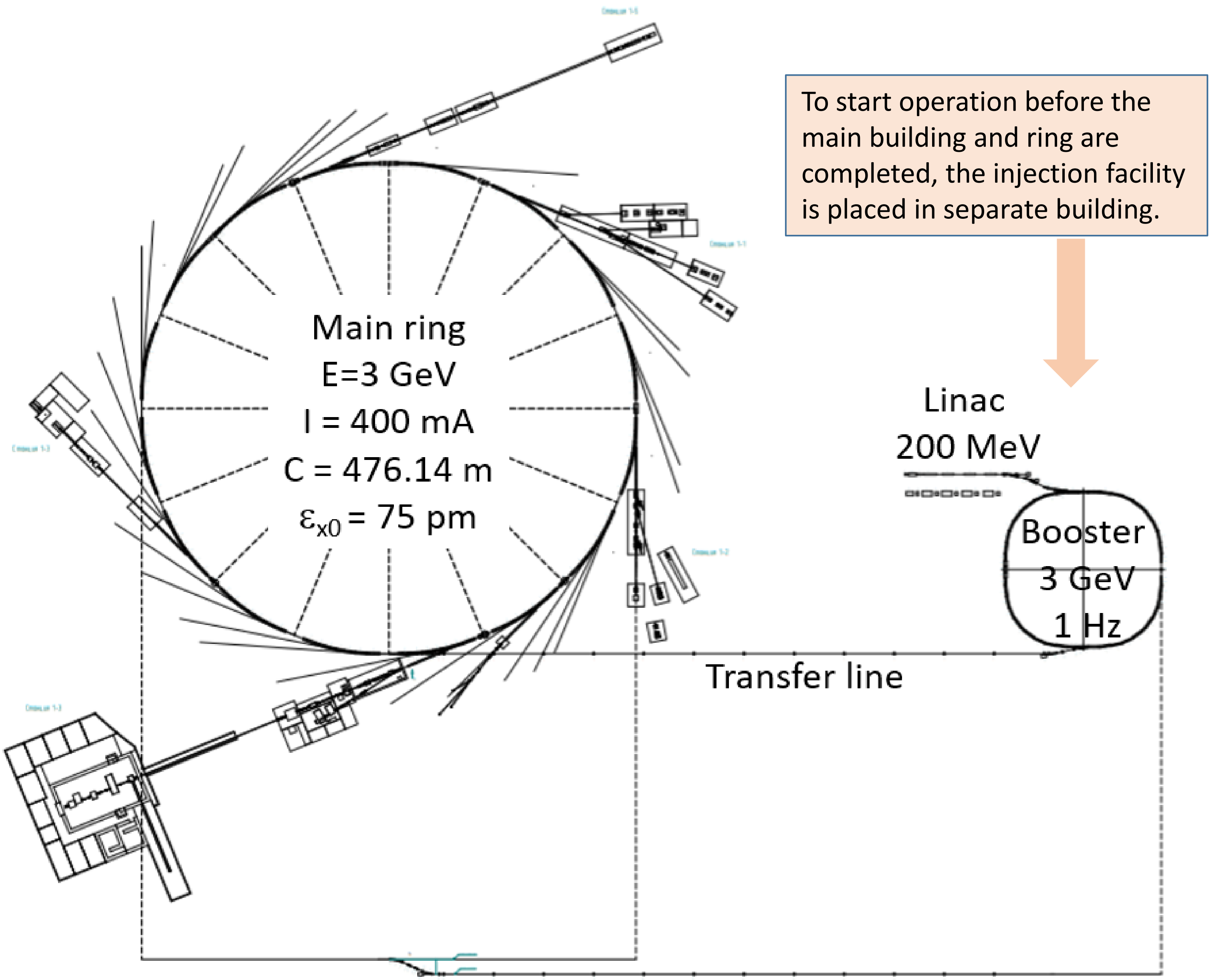
Kol’tsovo is a nice, ecological, modern town

Specifications and constraints

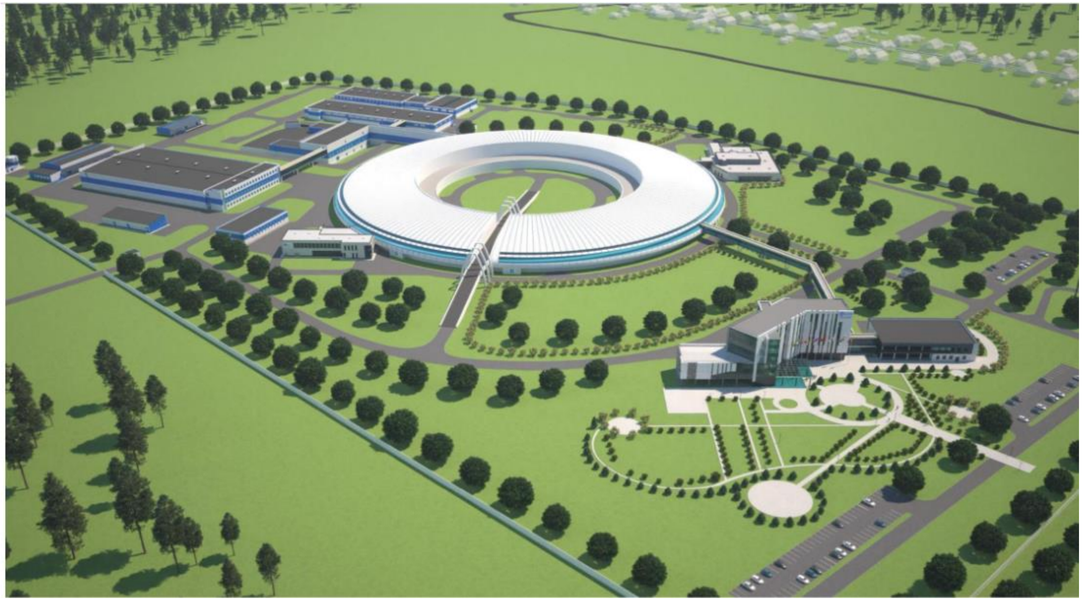
- Beam energy 3 GeV (short construction term)
- Circumference < 500 m (available ground area)
- Natural horizontal emittance $\leq$100 pm (zero current, zero coupling, no IDs)
- Injection complex *à la* NSLS II (150-200 MeV linac and full energy small size booster synchrotron) (short construction term)
- Traditional off-axis horizontal plane injection with four-kicker bump (reliability)
- Sufficient number of beamlines (users requirements)
  - From wigglers and undulators (straight sections)
  - Hard X-ray from strong field dipoles
  - Soft X-ray and VUV from weak field magnets (important for catalysis and chemical users)
- Simple, robust, proven solution when possible (reliability) (short construction term)

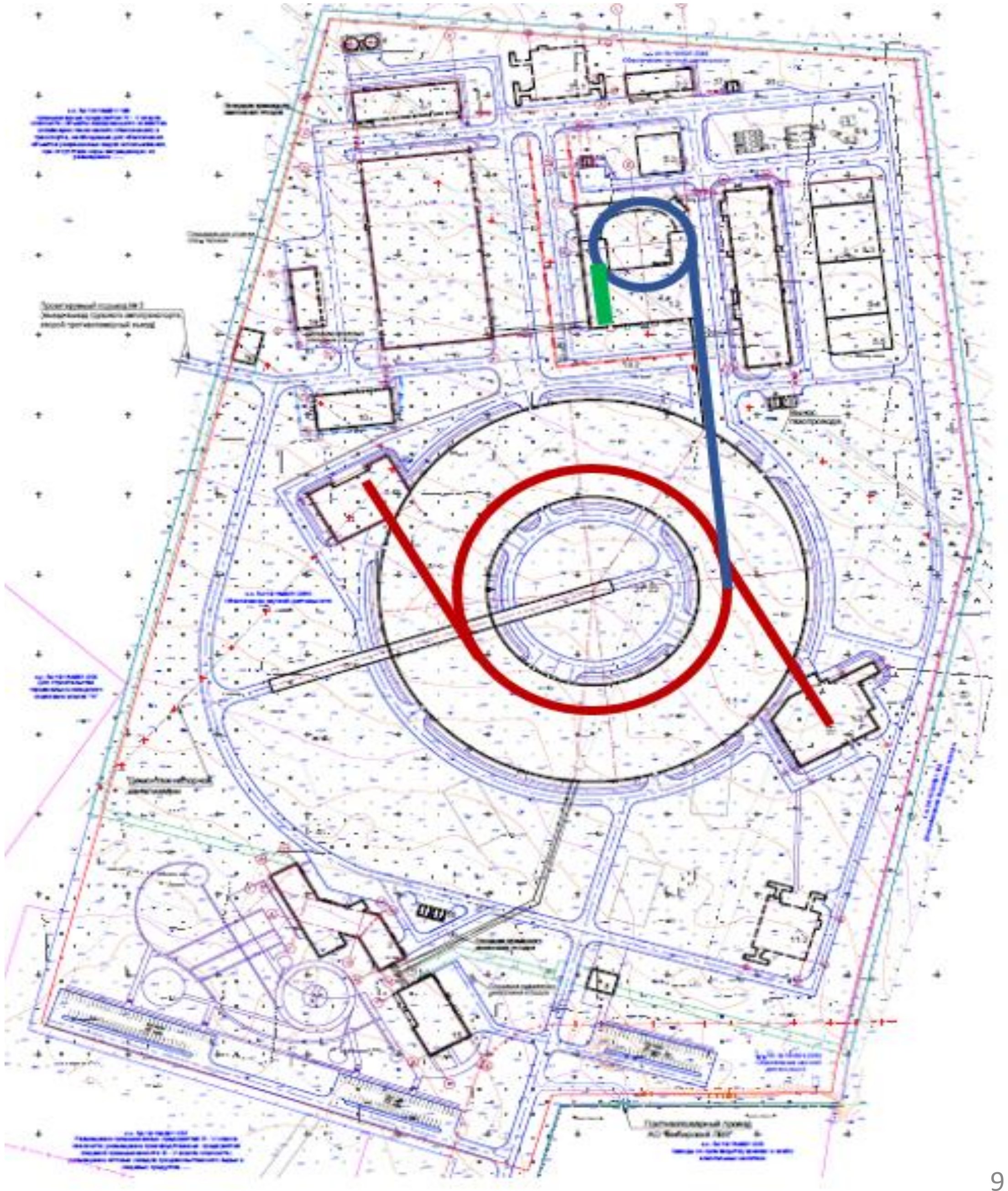
Configuration

- Linear accelerator with maximum energy 200 MeV
- Small size booster synchrotron with maximum energy 3 GeV and orbit length 158.7 m
- Electron storage ring 16-fold symmetry with 3 GeV energy and 476 m circumference

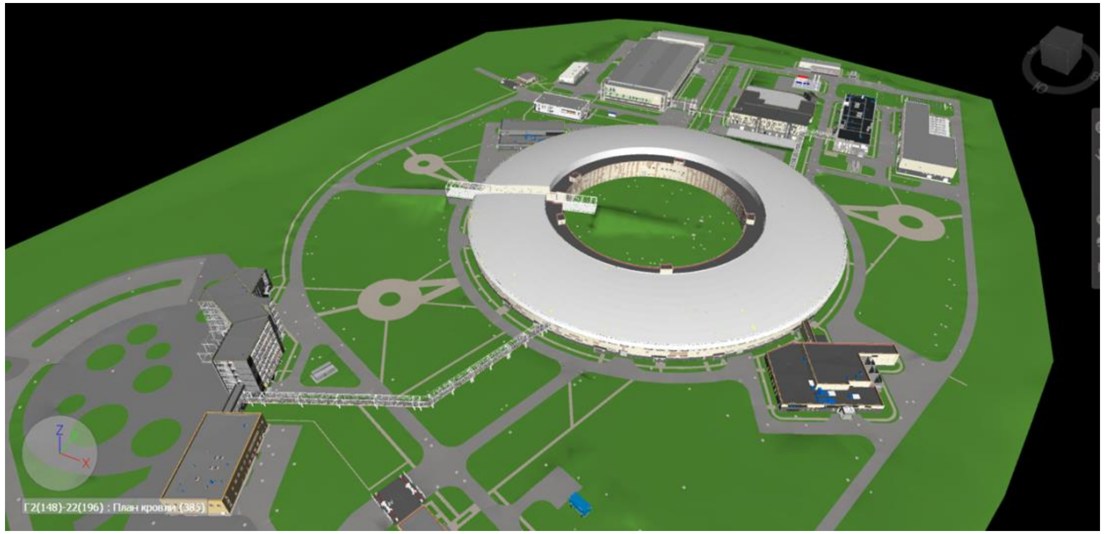


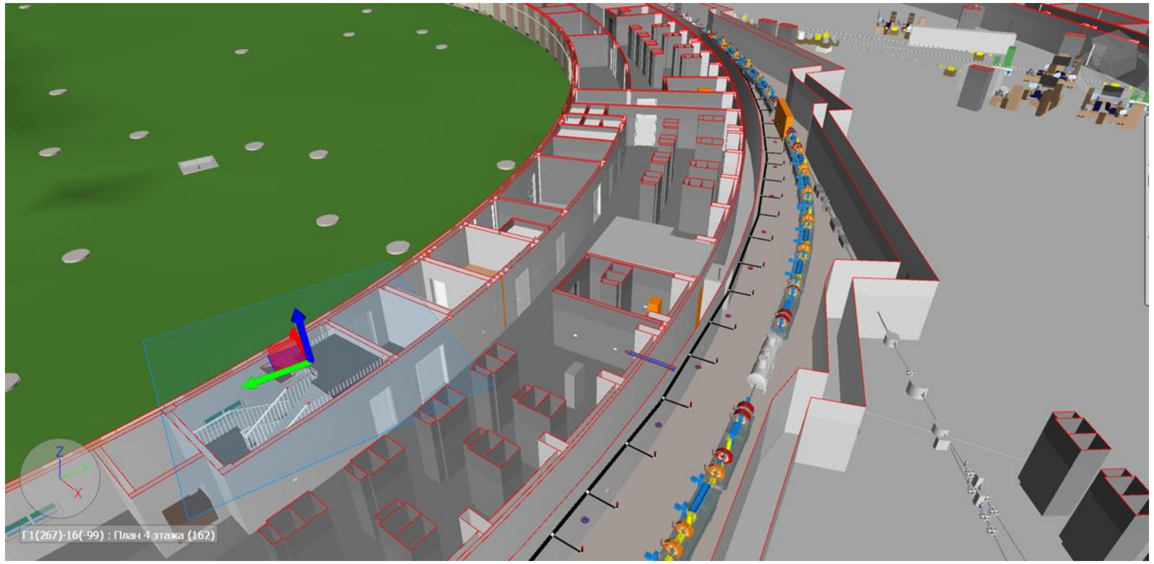
Architecture and site

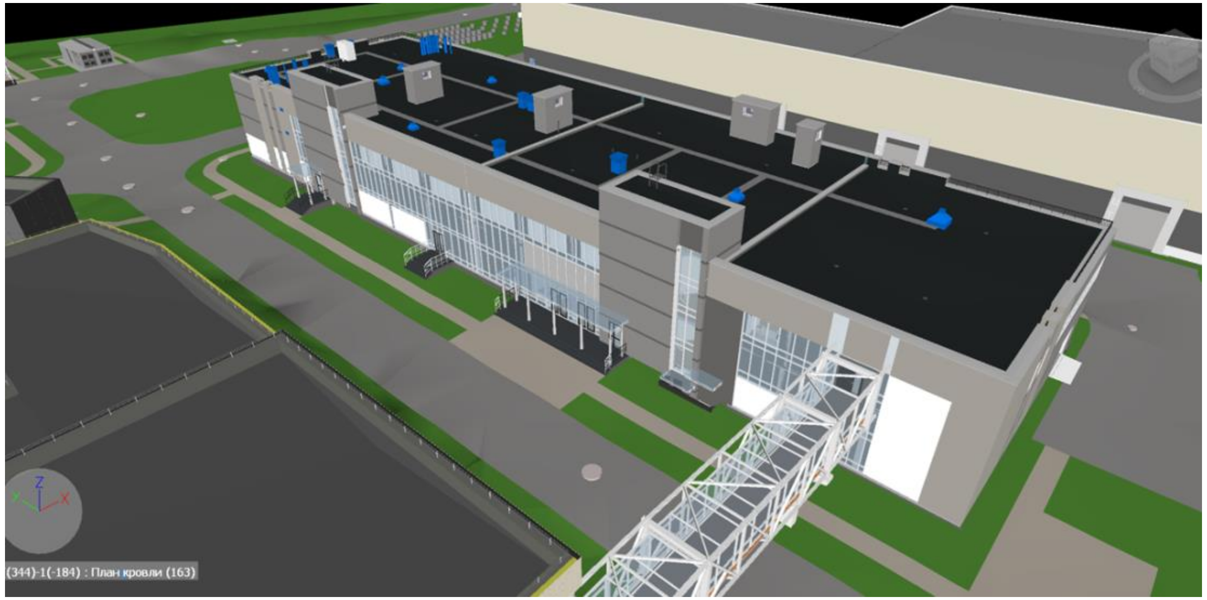


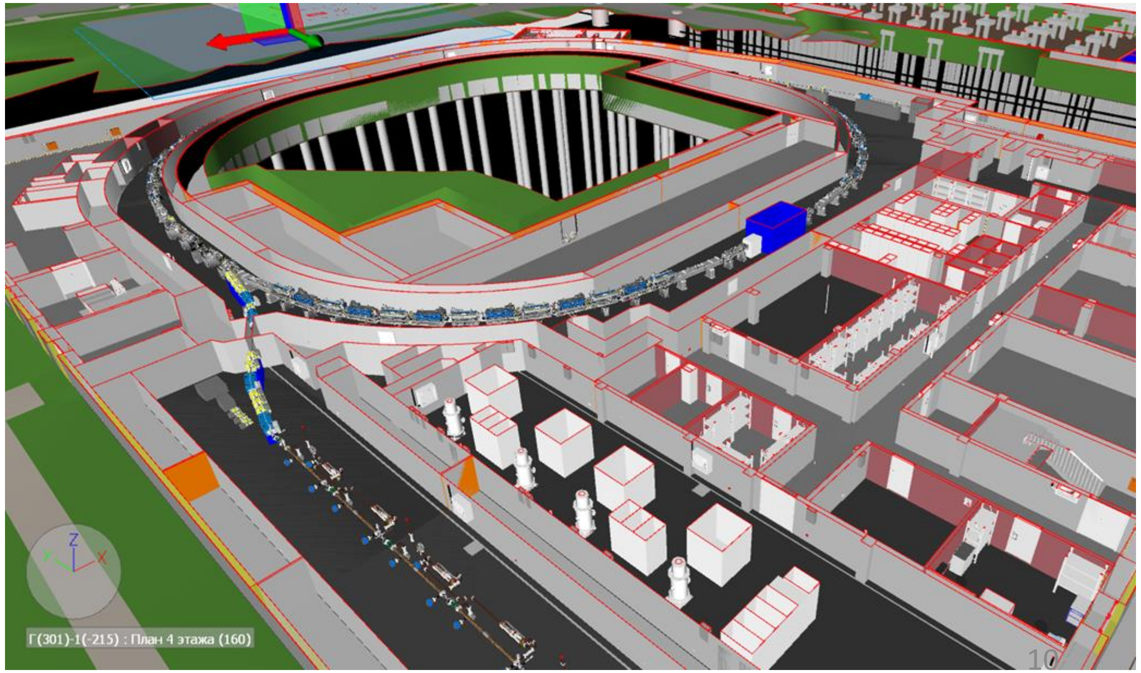


3D design is completed

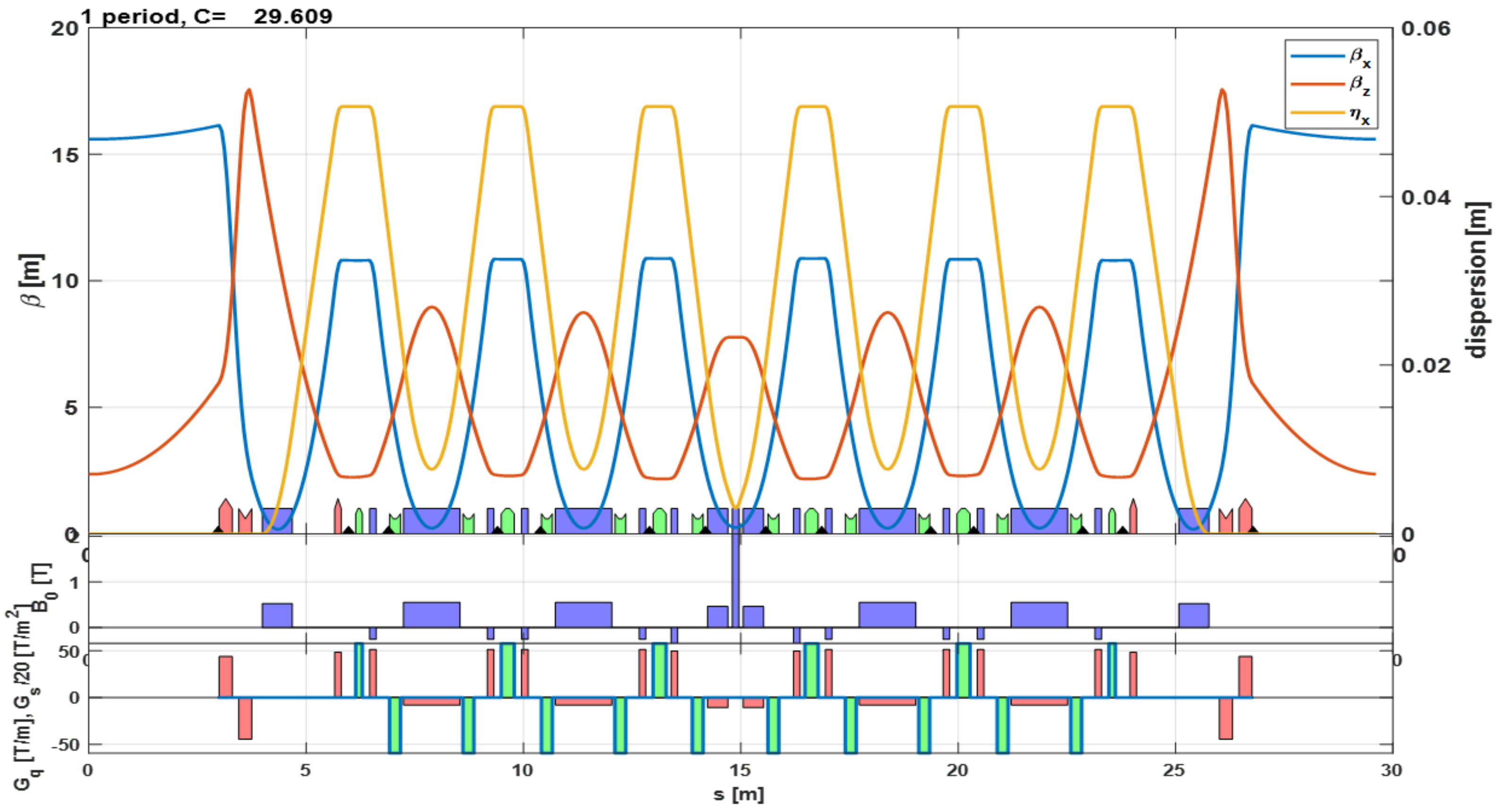








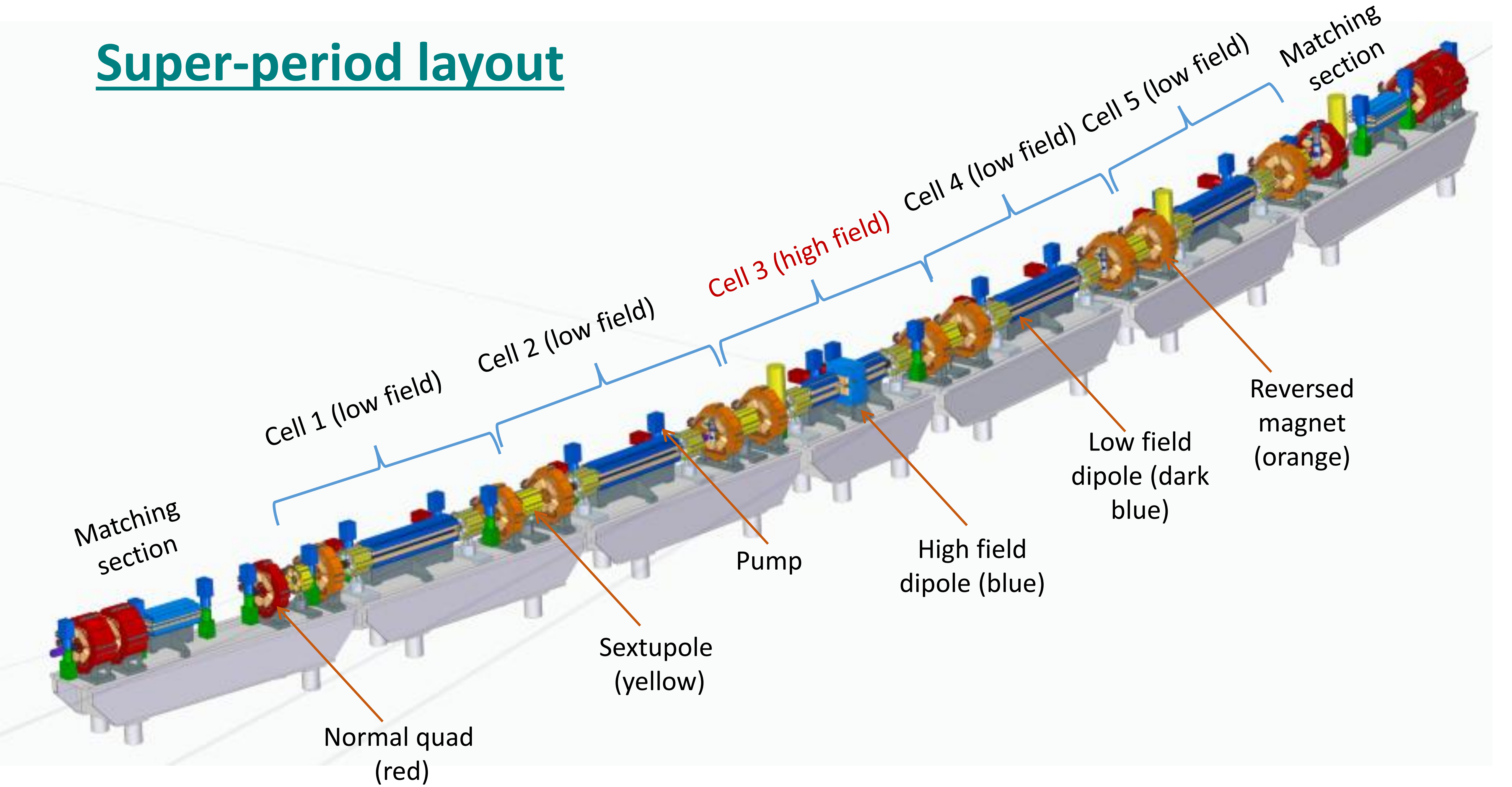
Optics and parameters



Energy, GeV	3
Symmetry	16
Circumference, m	476.14
Revolution period, μc	1.588
Horizontal emittance, pm	73.2
Energy spread	$1\cdot10^{-3}$
E loss per turn, keV	536
Betatron tunes, (*x*/*y*)	50.806 / 18.84
Compaction factor	$7.64\cdot10^{-5}$
Natural chromaticity, (*x*/*y*)	–149/–55
RF harmonic number	567
RF frequency, MHz	357
RF voltage, MV	0.77
Energy acceptance	±3 %
Synchrotron tune	$1.13\cdot10^{-3}$
Natural bunch length, mm	5.3
Partitions, (*x*/*e*)	1.94/1.06
Damping times, (*x*/*e*), ms	9.2/16.7

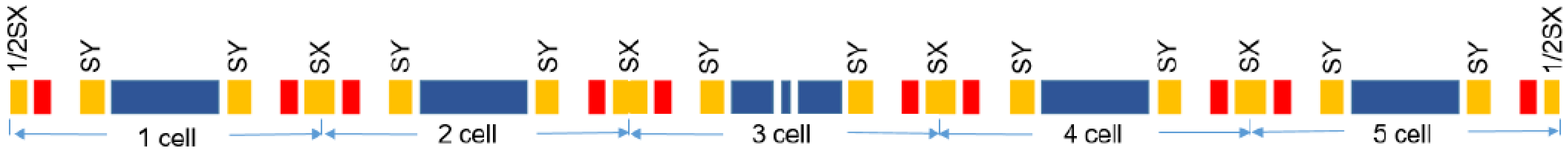
Main design principles: simple, fast for manufacture (minimum R&D), reliable.
Classical MBA with one 2 T permanent magnet is the middle. No longitudinal gradient magnets.

Super-period layout



Chromaticity correction

$(\xi_x/\xi_y) = -149/-55$

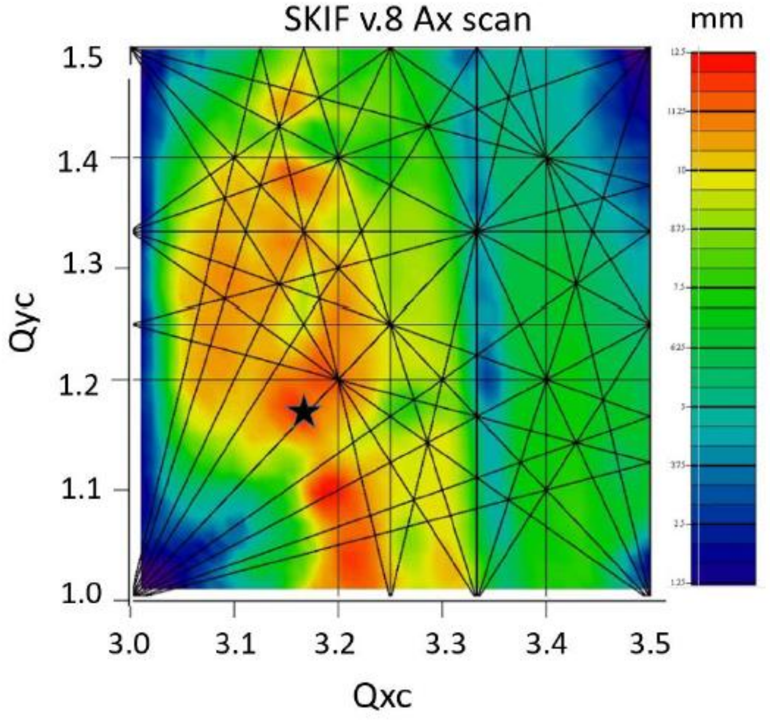


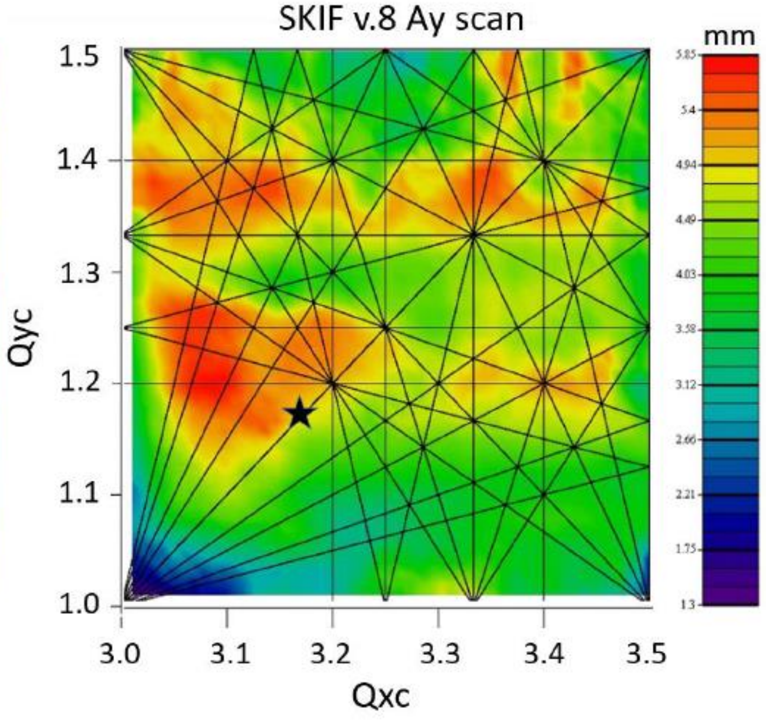
	l, м	B''_{nom}, Т/м²	$(K_2 l)_{nom}$, м⁻²	B''_{max}, Т/м²	$(K_2 l)_{max}$, м⁻²
SY	0.25	–2379	–59.48	–2800	–70
SX	0.30	2313	69.39	2800	84
1/2SX	0.15	2313	34.70	2800	42

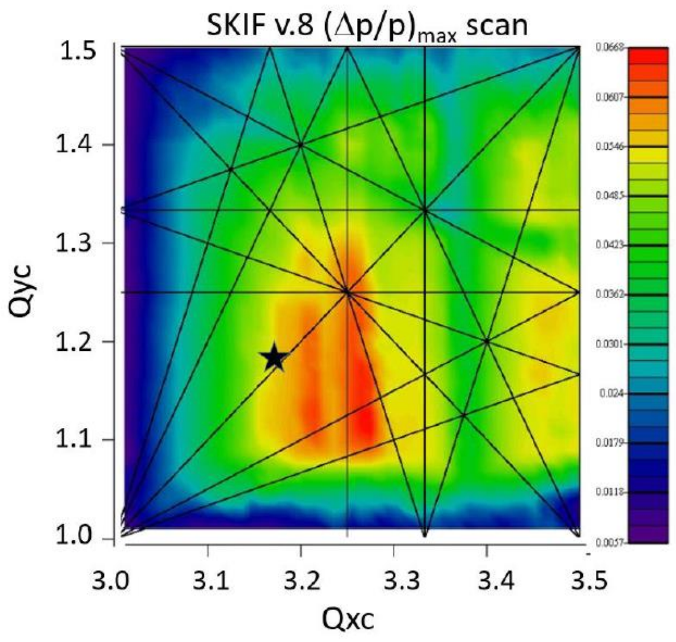
Only two sextupole families compensate natural chromaticity and optimize dynamic aperture and momentum acceptance. No other multipoles (octupoles or harmonic sextupoles) are applied.

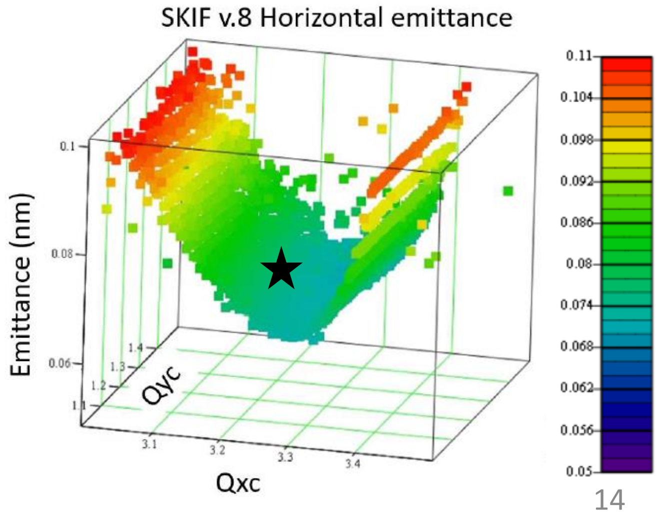
DA optimization (one super-period)

Tunes are for one super-period. ★ Chosen tune point



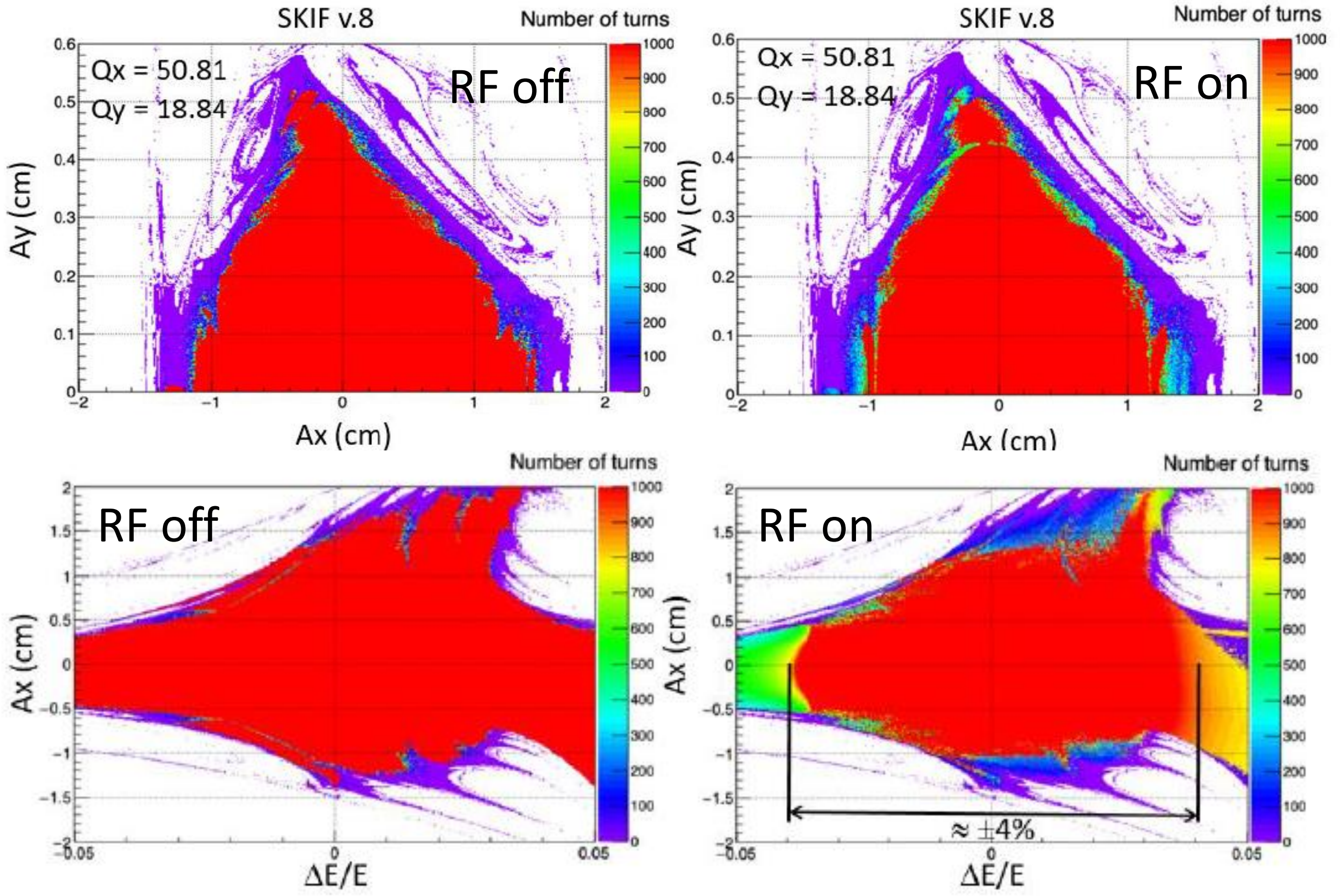




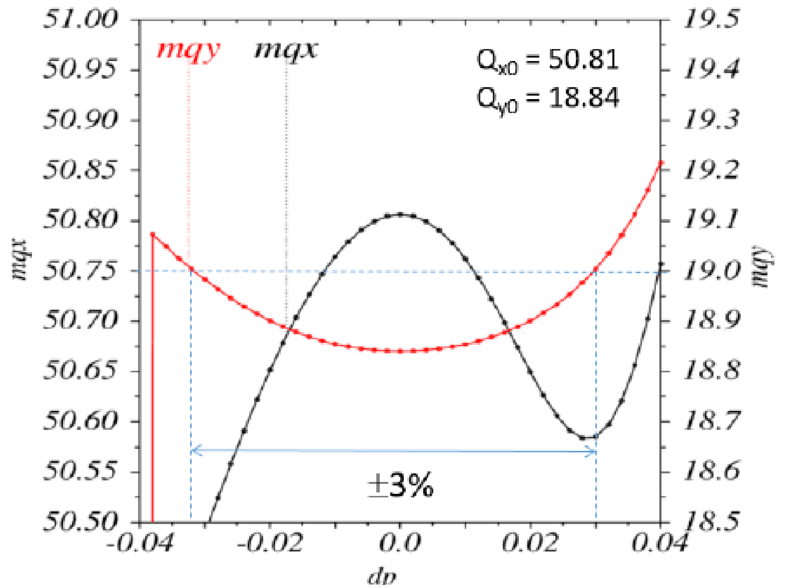


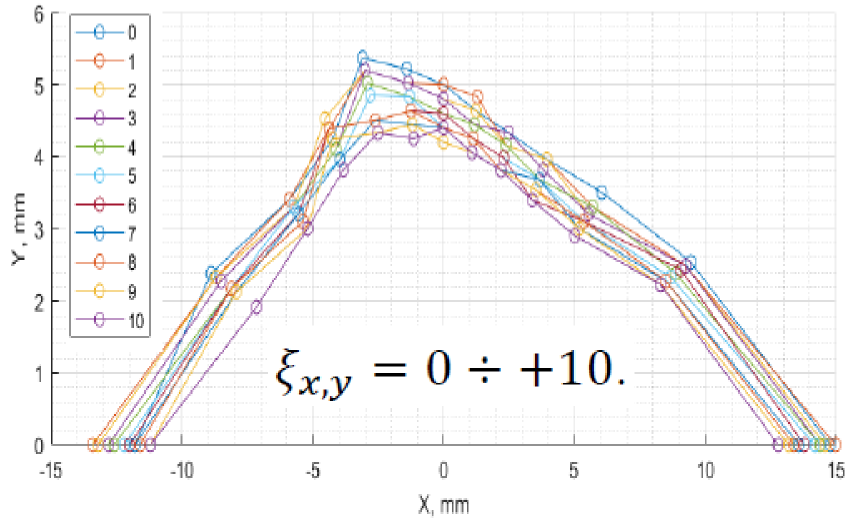
Betatron tunes, phase advances between chromatic sextupoles and their strength were carefully adjusted to maximize dynamic aperture and momentum acceptance.

DA and momentum acceptance



Survival plots. Red is stable during 1000 revolutions. Only two sextupole families are enough to get sufficient dynamic aperture and momentum acceptance. $\beta_x = 15.6$ м, $\beta_y = 2.4$ м

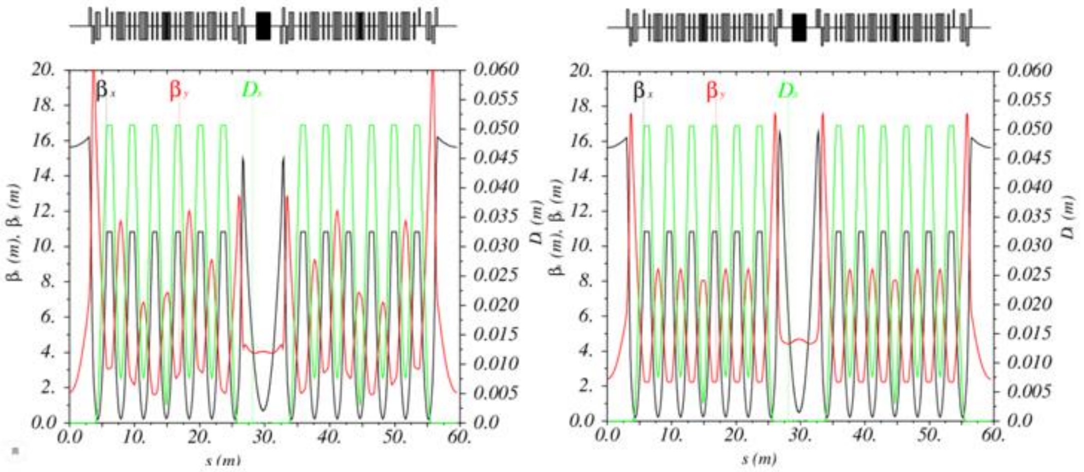




Insertion devices

To extend the spectrum in the hard X-ray region, we plan to use superconducting IDs.

№	Experimental station	ID	B (T)	λ_w (mm)	N_{per}	P_{SR} (kW)
1-1	Microfocus (5-47 keV)	SCU	1.2	15.6	128	7.2
1-2	Structural analysis (5-40 keV)	SCU	1.2	15.6	128	7.2
1-3	Fast dynamic processes (15-100 keV)	SCW	4	33.7	60	75
1-4	XAFS and magnetic dichroism (2.5-35 keV)	SCU	1.2	15.6	128	7.2
1-5	Hard X-ray imagine (25-200 keV)	SCW	4	33.7	60	75
1-6	Photoelectron spectroscopy (0.01-2 keV)	EMU	0.5	100/200	20/10	1.8



Before correction   After correction

Optics with 1 SCW

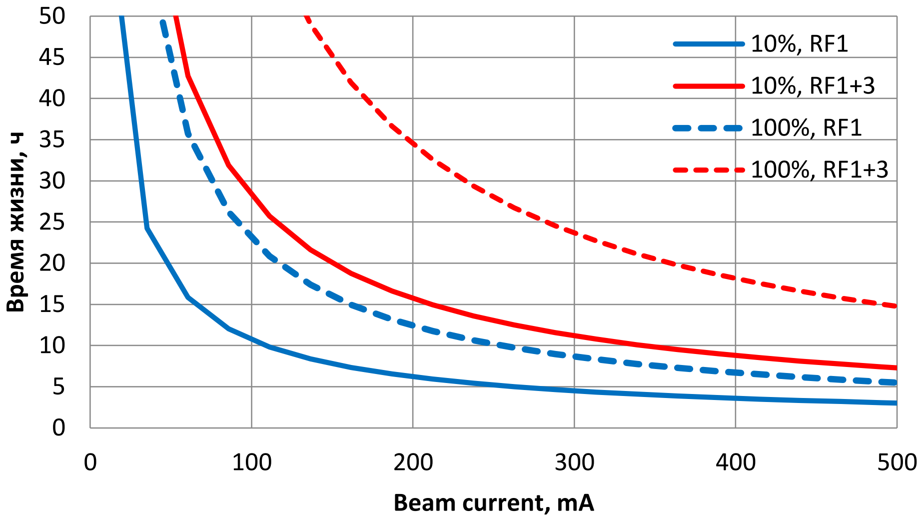
Parameter	Bare	1U	1W	2W	3W
ε_{xtot}, pm	73	72	74	75	76
$\sigma_E/E{\cdot}10^3$	1.03	1.02	1.24	1.32	1.36
ΔE/turn, keV	534	548	720	904	1090
U_{RF}, MV	0.85	0.85	1.1	1.27	1.48
$J_{x/s}$	1.94/1.06	1.91/1.09	1.68/1.32	1.55/1.45	1.46/1.54
$\tau_{x,y,s}$, ms	9/18/17	9/17/16	8/13/10	7/10/7	6/9/6

For baseline lattice, the emittance does not depend on IDs.

IBS study

400 mA in 510 bunches, U_0=534 keV/turn, V_{RF}=0.845 MV ($\Delta E/E=\pm 3\%$)

RF1 – main accelerating system, RF1+3 – third harmonic RF elongate the bunch threefold.



	10%		100%	
	RF1	RF1+3	RF1	RF1+3
ε_{x0}, pm	72.7			
$\varepsilon_{xcoupled}$, pm	66		36	
ε_{xIBS}, pm	113	90	59	47
ε_{yIBS}, pm	11	9	59	47
$\sigma_E/E \times 10^4$ (0/IBS)	10.3/12.4	10.3/11.4	10.3/11.4	10.3/10.9
σ_l (mm) (0/IBS)	5.3/5.9	15.8/16.2	5.3/5.4	15.8/15.4
τ_{TIBS} (hours)	3.2	7.9	6.2	17

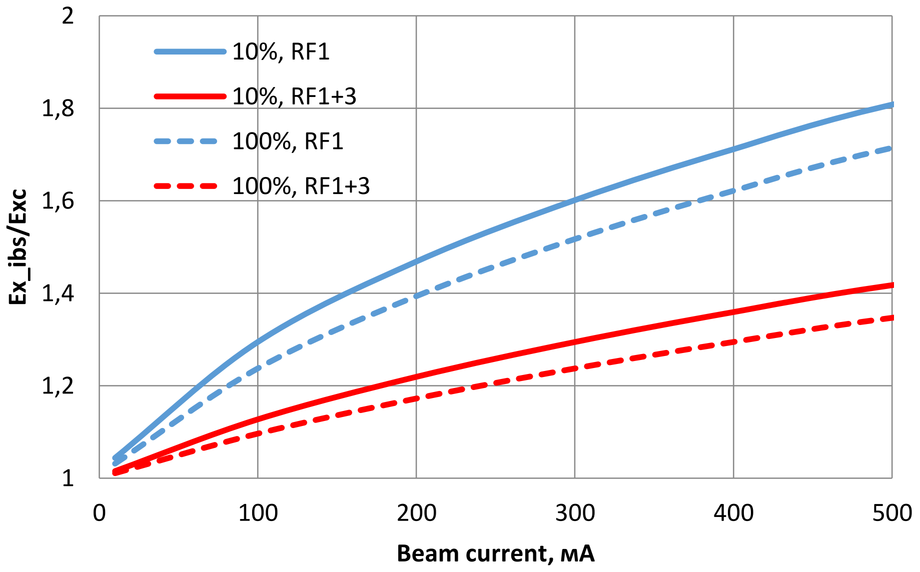
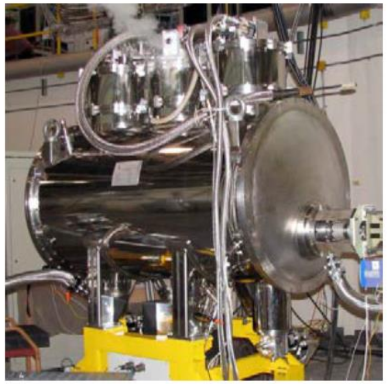


Illustration mix

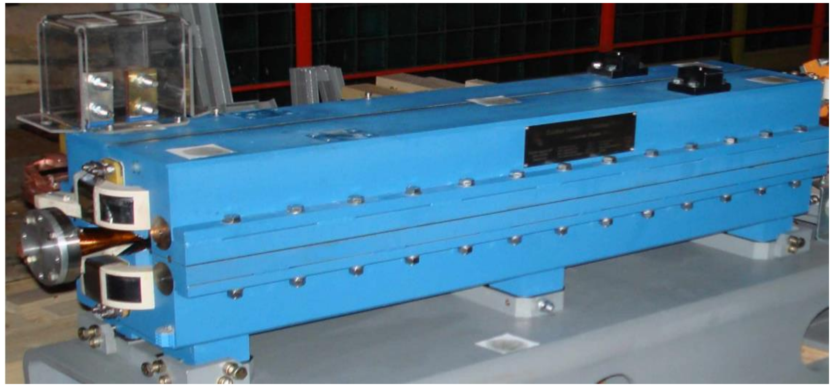
Linac cells production

49-pole 4.2 Tesla, λ=48 mm superconducting wiggler for Diamond Light source. 2009

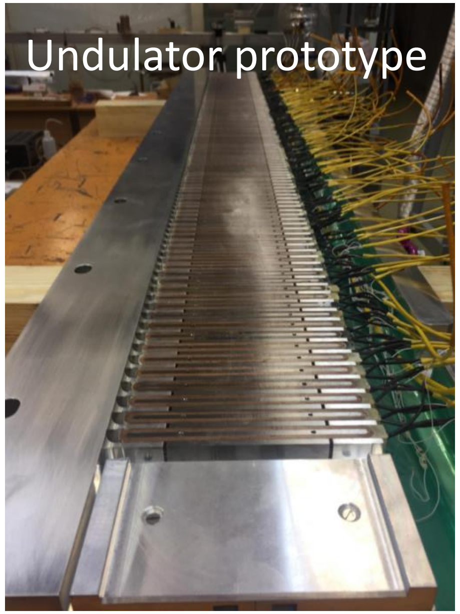


27-pole 4.2 Tesla, λ=48 mm superconducting wiggler for Canadian Light source. 2007

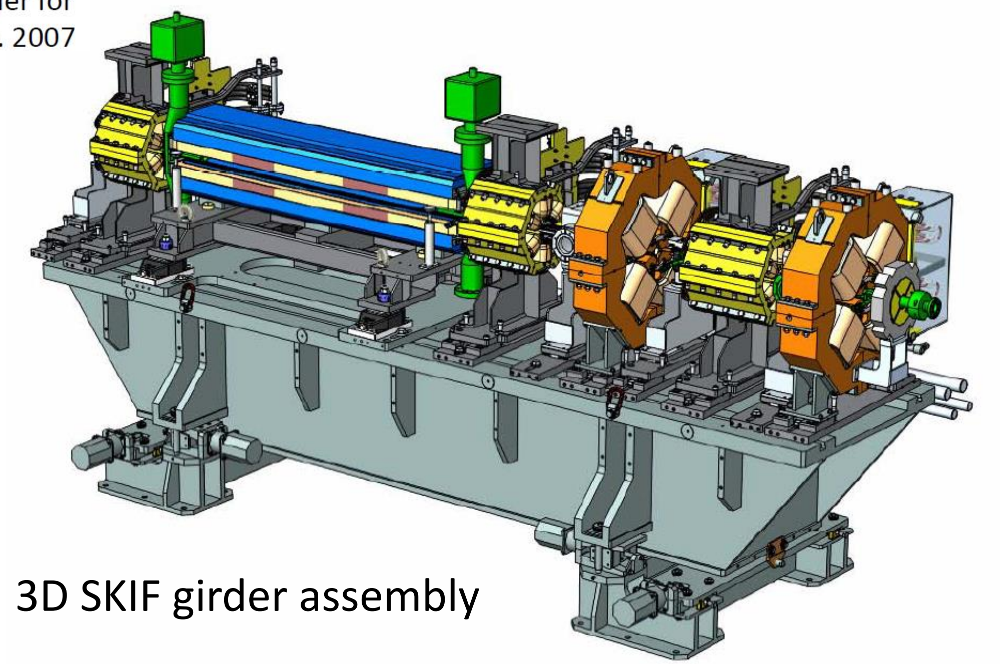
Linac RF loads



Booster dipole prototype

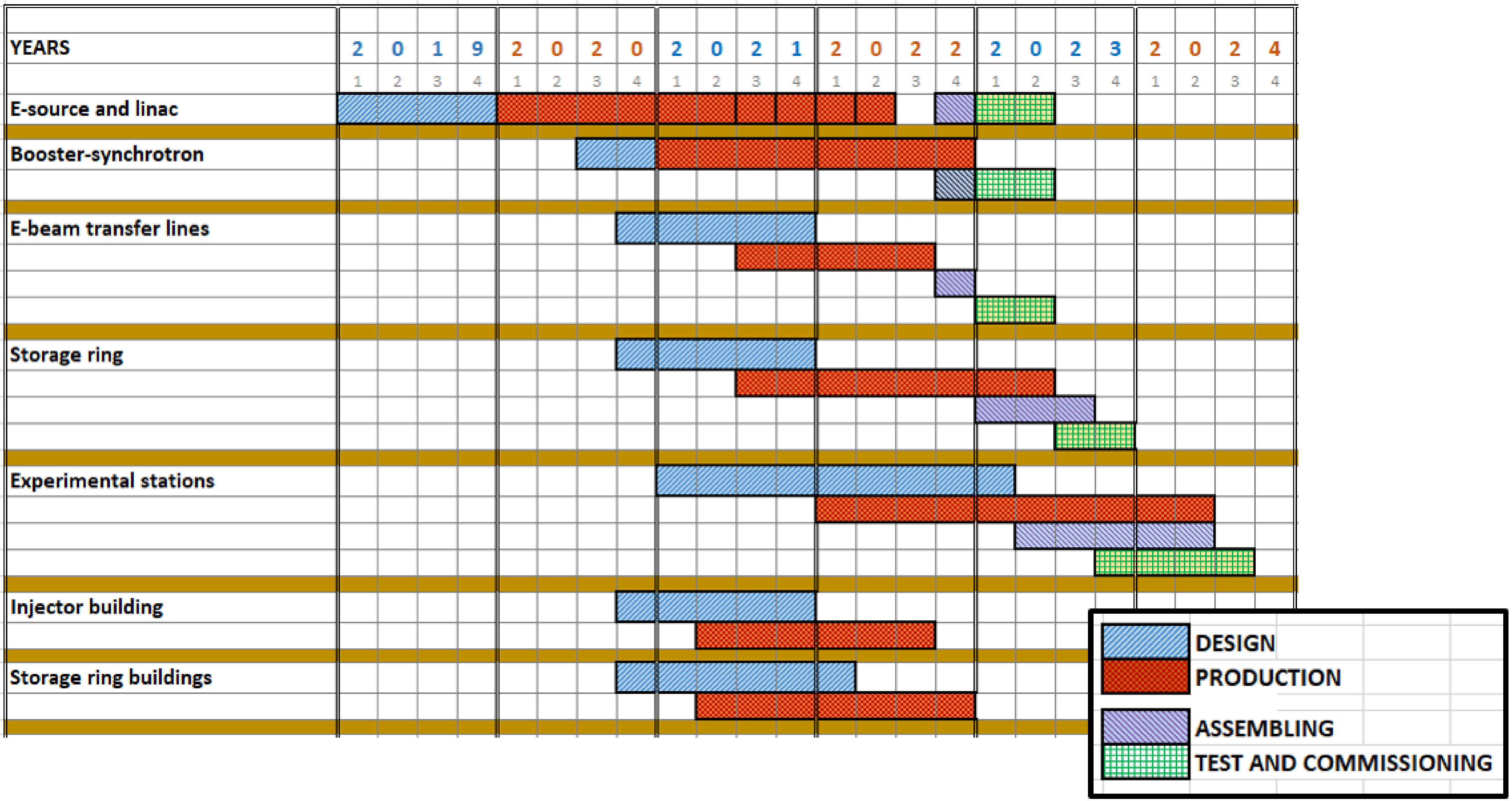


Undulator prototype



3D SKIF girder assembly

Timeline


YEARS
2019
2020
2021
2022
2023
2024
1 2 3 4
E-source and linac
Booster-synchrotron
E-beam transfer lines
Storage ring
Experimental stations
Injector building
Storage ring buildings
DESIGN
PRODUCTION
ASSEMBLING
TEST AND COMMISSIONING

Summary

- Design of the new Novosibirsk 4th generation light source SKIF provides natural emittance 73 pm for 3 GeV beam energy and 476 m orbit length.
- Only two sextupole families provide dynamic aperture and momentum acceptance sufficient for good beam lifetime and tradition well-proven injection.
- SKIF has 16 6-m-long straight sections (14 are for IDs). Optical functions in the straight sections are optimized to accommodate strong field IDs.
- 30 beam lines are foreseen: 14 are from IDs, 8 high field permanent magnets (2.1 T) and 8 from regular cell magnets (0.5 T).
- Magnet types are minimized for the cost and production time saving.
- Civil engineering and buildings design is completed.
- Linac and booster is under manufacturing.
- Storage ring production is expected will start next summer.