FIRST RESULTS OF SIBERIA-2 STORAGE RING OPERATION WITH 7.5 T SUPERCONDUCTING WIGGLER

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Abstract

7.5 T 19-pole superconducting wiggler has been installed on SIBERIA-2 storage ring in December 2007. First results of an operation of Siberia-2 with the wiggler are described. An influence of the wiggler on betatron tunes, closed orbit, betatron functions and other beam parameters is discussed. Calculated and measured influence on beam parameters is compared..

TOPICS

1. Storage ring SIBERIA-2
2. 7.5 T superconducting wiggler
3. Wiggler testing before installation on the ring
4. Wiggler performance on SIBERIA-2 ring

KCSR accelerator facility layout

1. Linac

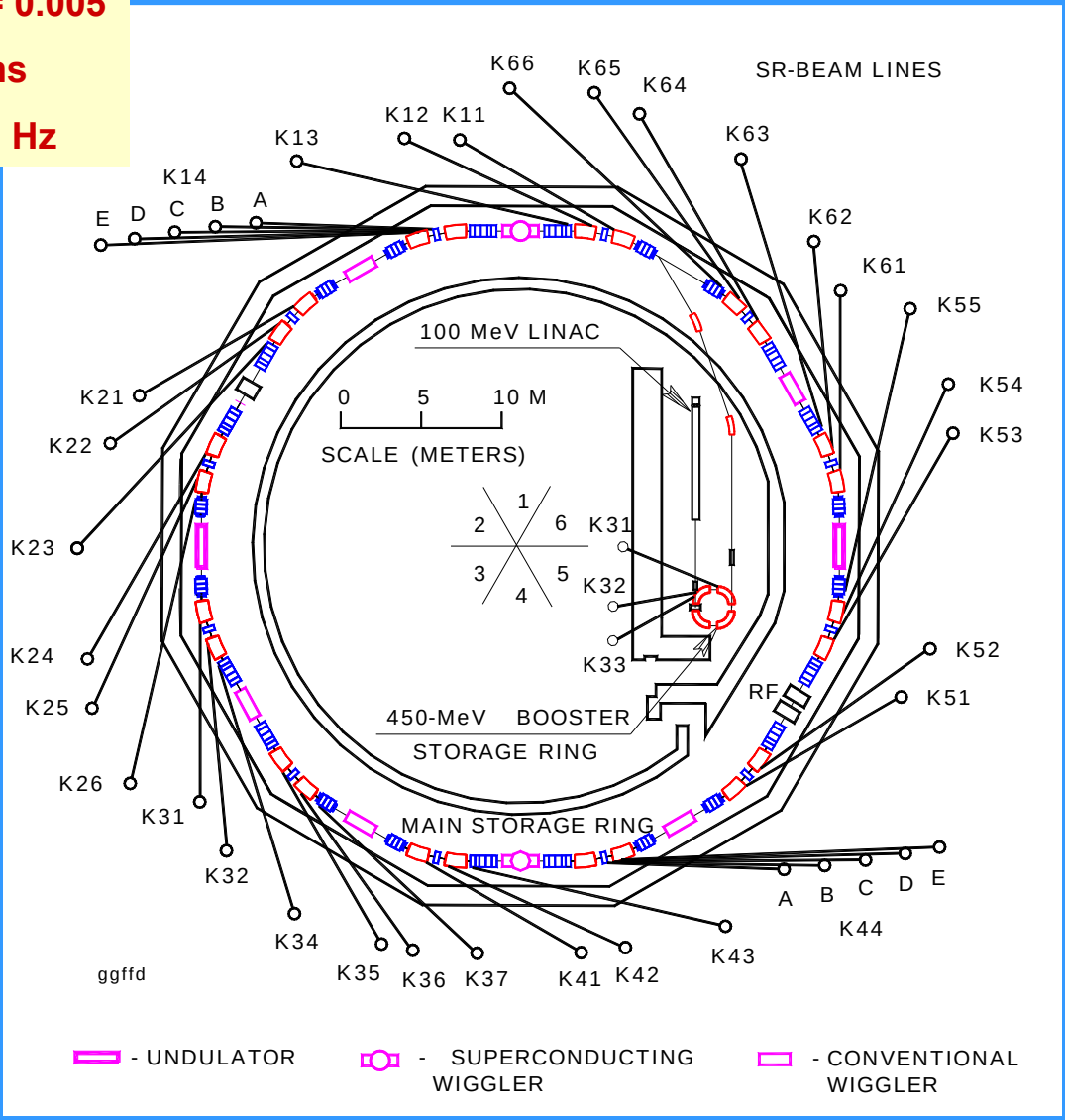
E = 80 MeV

I = 0.2 A

$\Delta E/E = 0.005$

T= 18 ns

F_{rep} = 1 Hz



2. Siberia-1 storage ring

E = 450 MeV

I = 0.2 – 0.3 A (single bunch)

C = 8.68 m

B = 1.5 T

T_0 = 29 ns

T rep = 25 s

3. Siberia-2 storage ring

E = 2500 МэВ

I = 0.3 A (multibunch)

C = 124.13 m

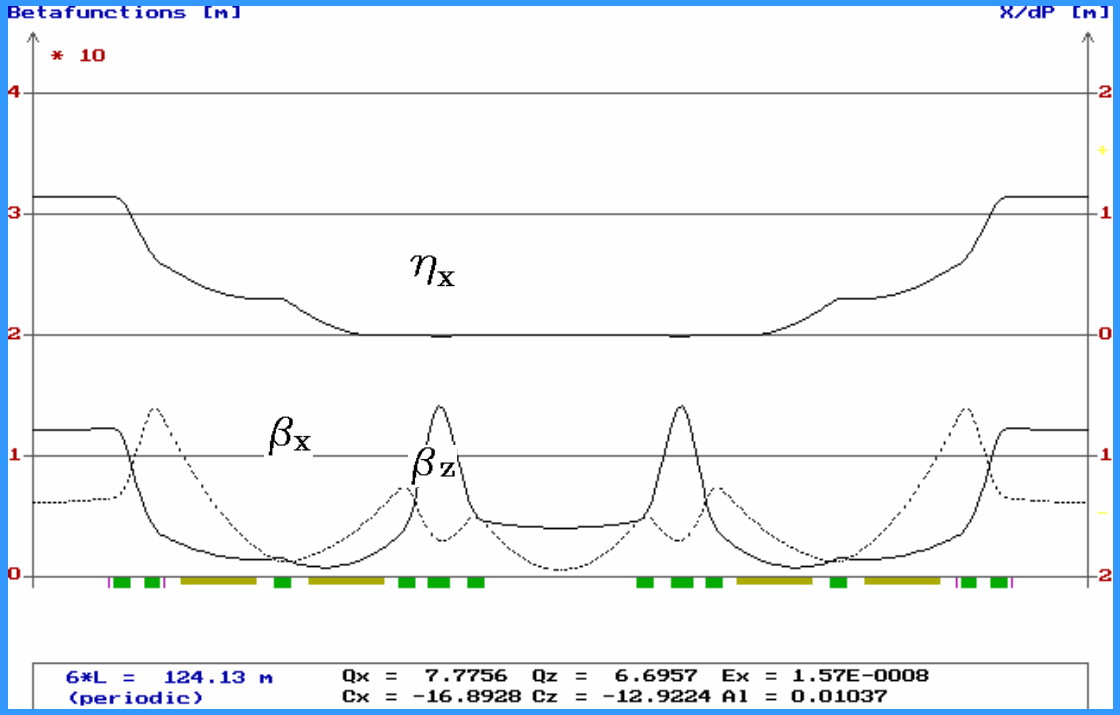
B = 1.7 T

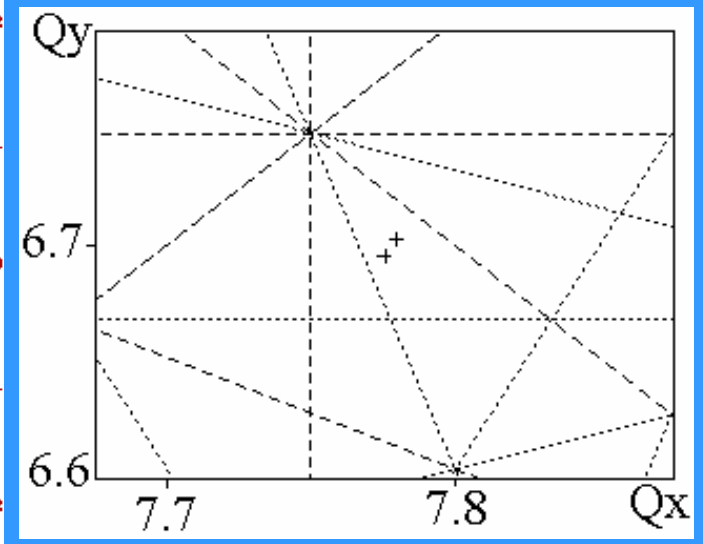
T_0 = 414 ns

τ = 5 hrs

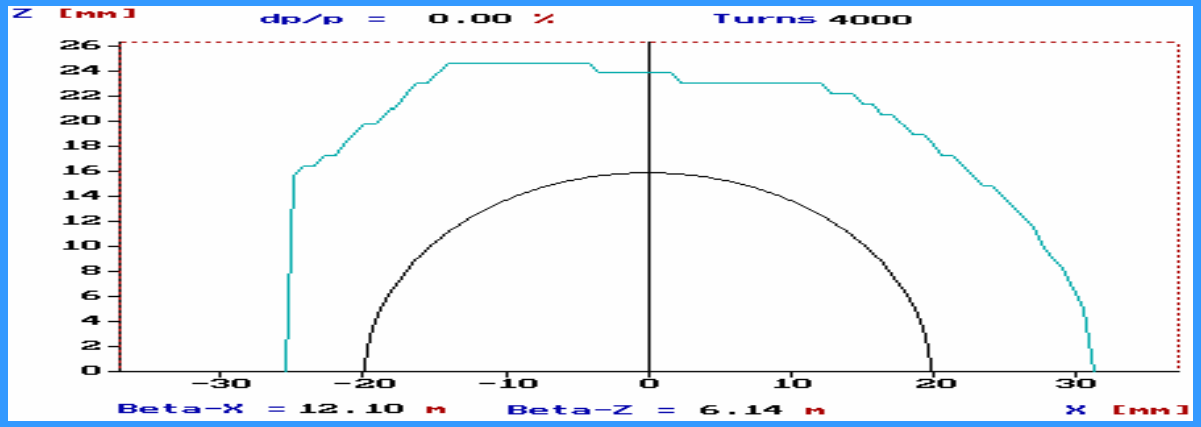
4. Two transfer lines

Siberia-2 optical functions and DA





$\nu x = 7.772 \quad \nu y = 6.692$



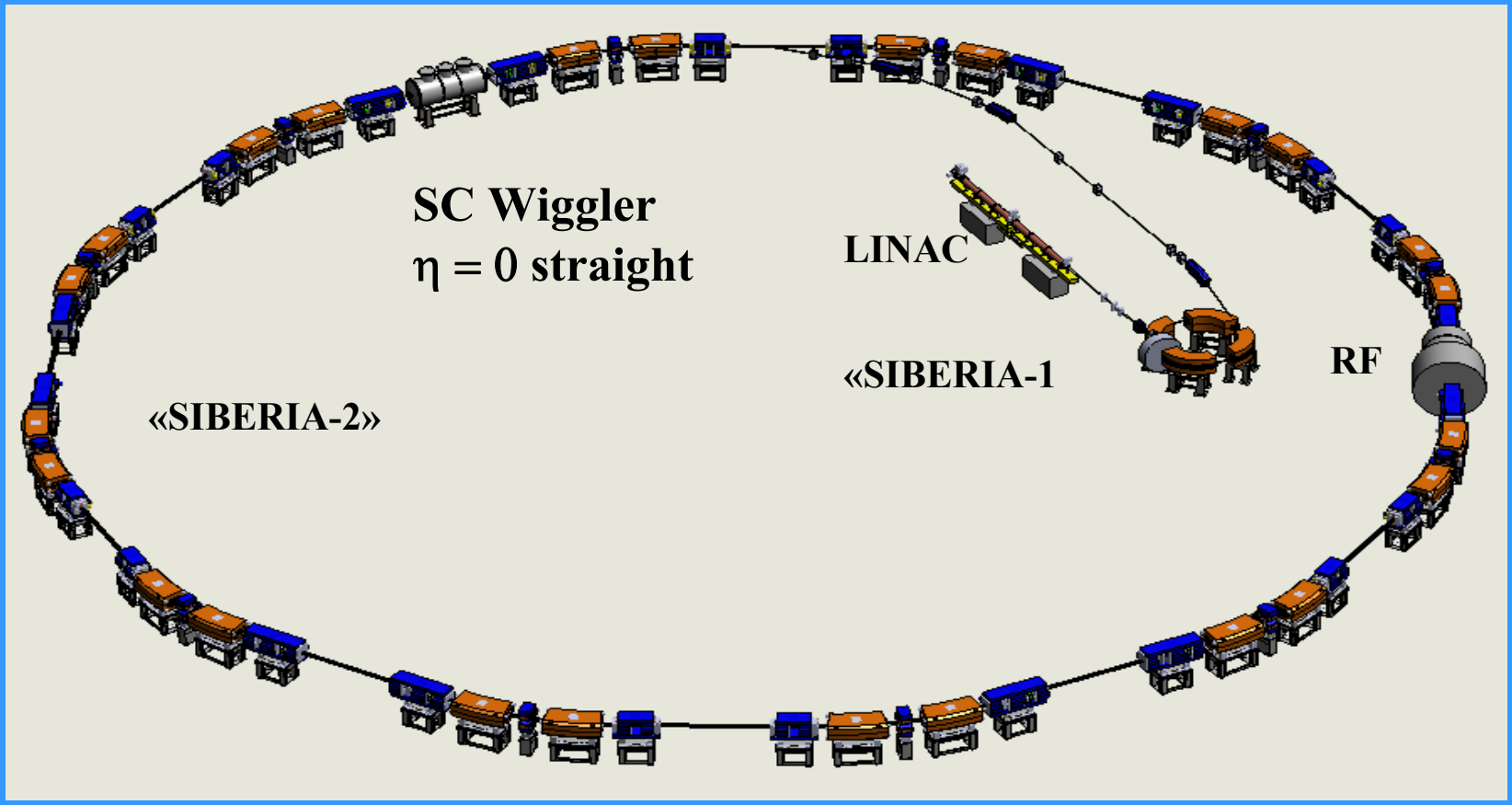
$2\nu x + 2\nu y = 29$,

$3\nu x + \nu y = 30$

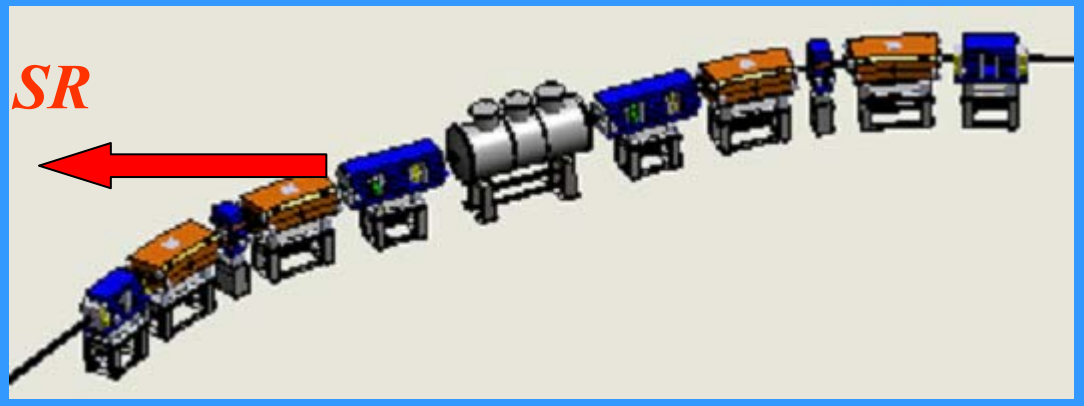
Main parameters of Siberia-1 and Siberia-2 rings

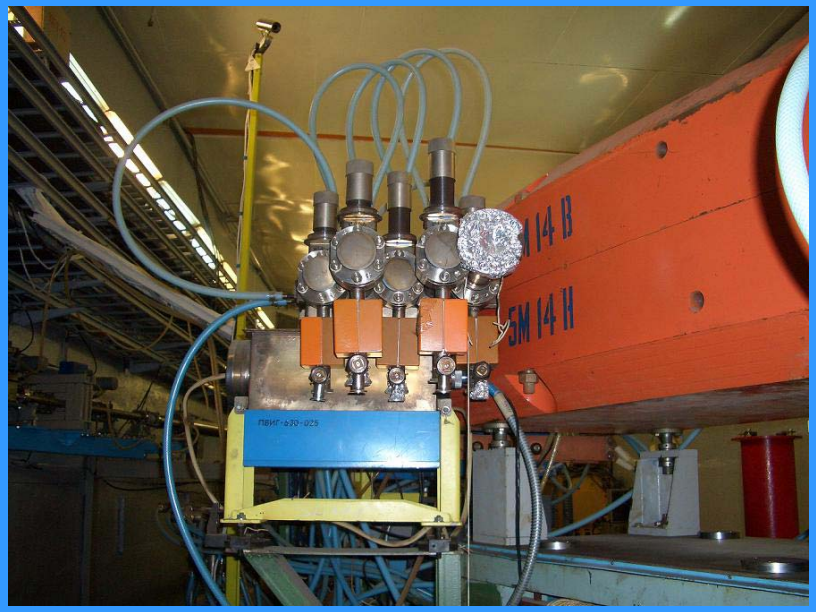
Parameter	Siberia-2	Siberia-1
Energy	2.5 GeV	0.45 GeV
Circumference	124.13 m	8.68 m
Optical structure	Modified DBA	FODO
Superperiods	6	1
Bet. tunes: nx, ny	7.772; 6.692	0.793; 0.895
Mom.compaction	0,0104	1,64
Damping *x ,y, s, ms*	3.04; 3.17; 1.49	7.15; 7.15; 3.57
Hor. emittance	78-98 nm-rad	880 nm-rad
RF harmonic	75	1
Energy spread	0,000953	0,00034
Dipole field: By	1.7 T	1.5 T
ID space	2x3m(eta=0) 5x3.2m(eta≠0)	
Bunch length:		
sigma (without IDs)	1.84 cm	30 cm
SR pulse duration	0.14 ns FWHM	2.35 ns FWHM
SR pulse spacing	5.5-414 ns	28.9 ns

KCSR with SC wiggler

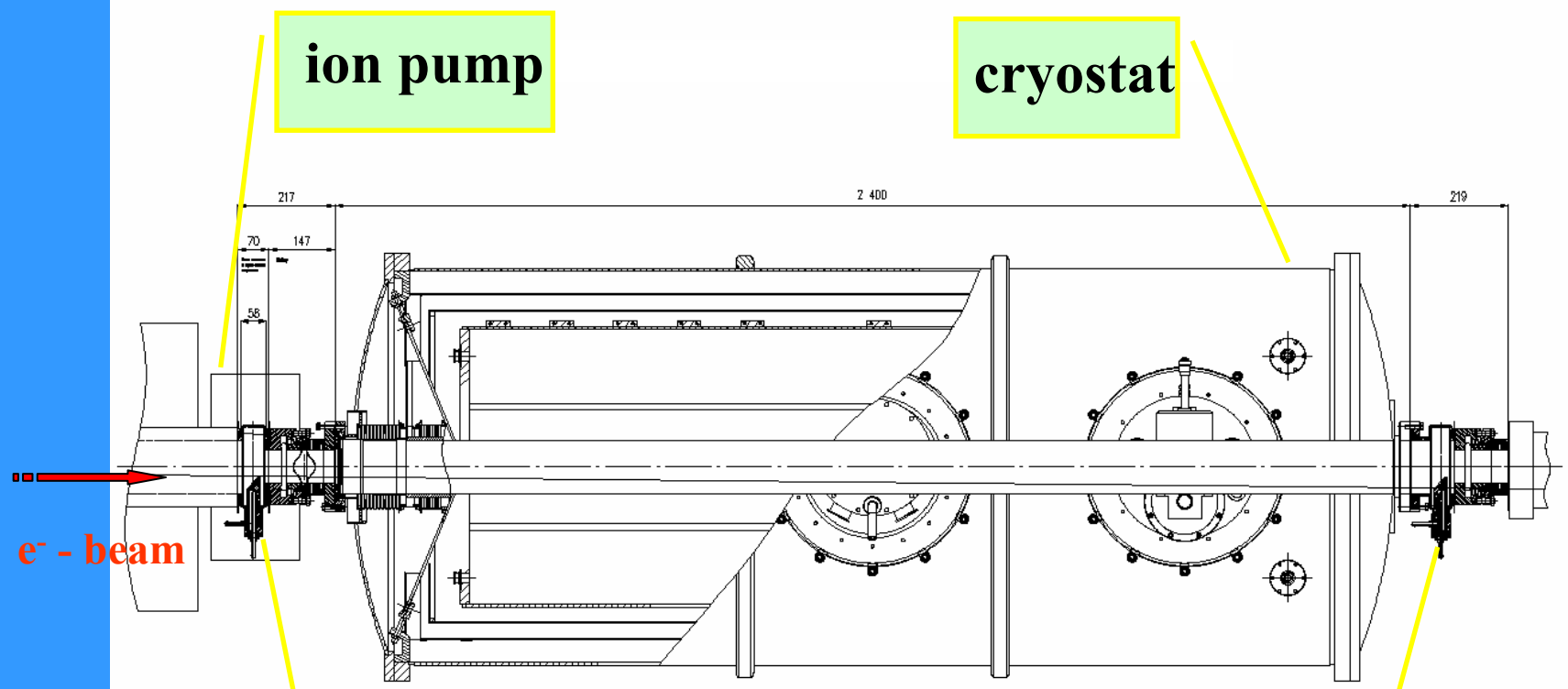


Scheme of SR beam extraction from SC wiggler

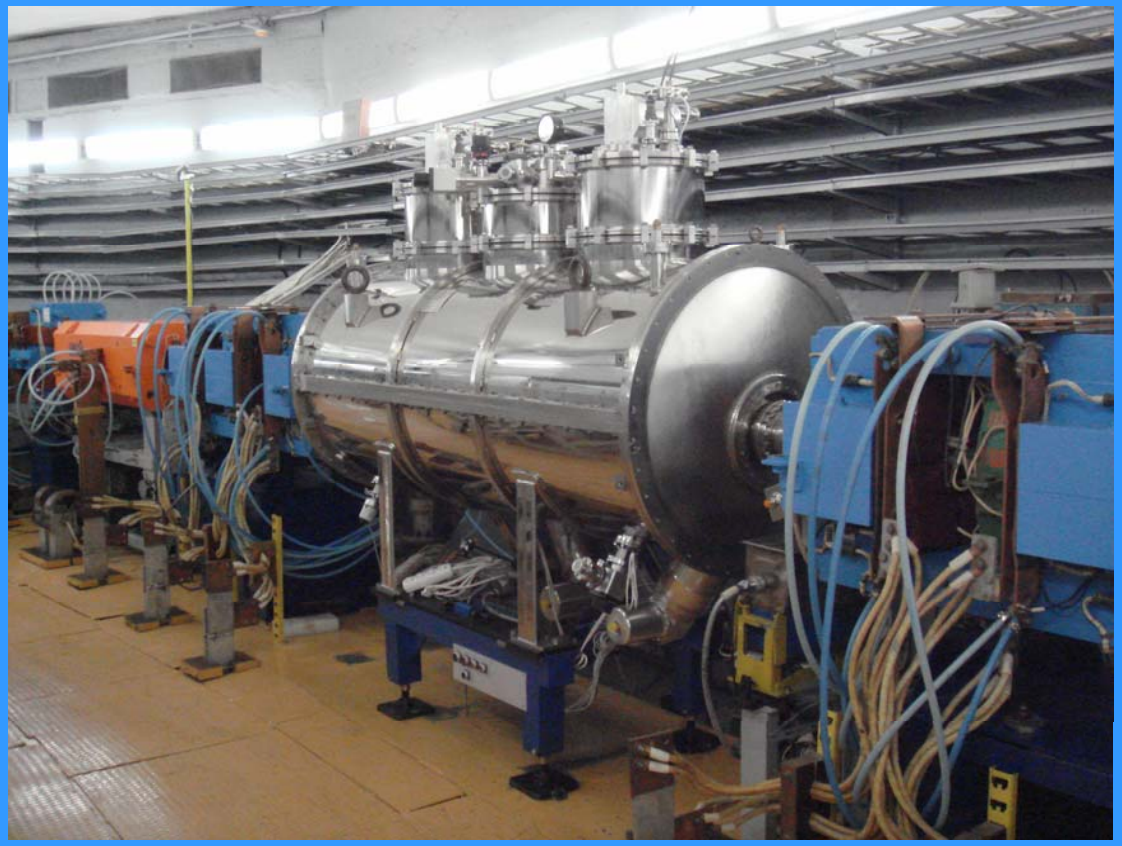




Straight section of SIBERIA-2 with wiggler



Superconducting wiggler in dispersion free straight section of SIBERIA-2. 25 December 2007



MPSCW: NbTi coils

E=2.5 GeV, I=0.1-0.3 A

B= 3 - 7.5 T, Npoles=19+2

λ_{wig} = 164 mm

Eph crit. = 31.2 keV

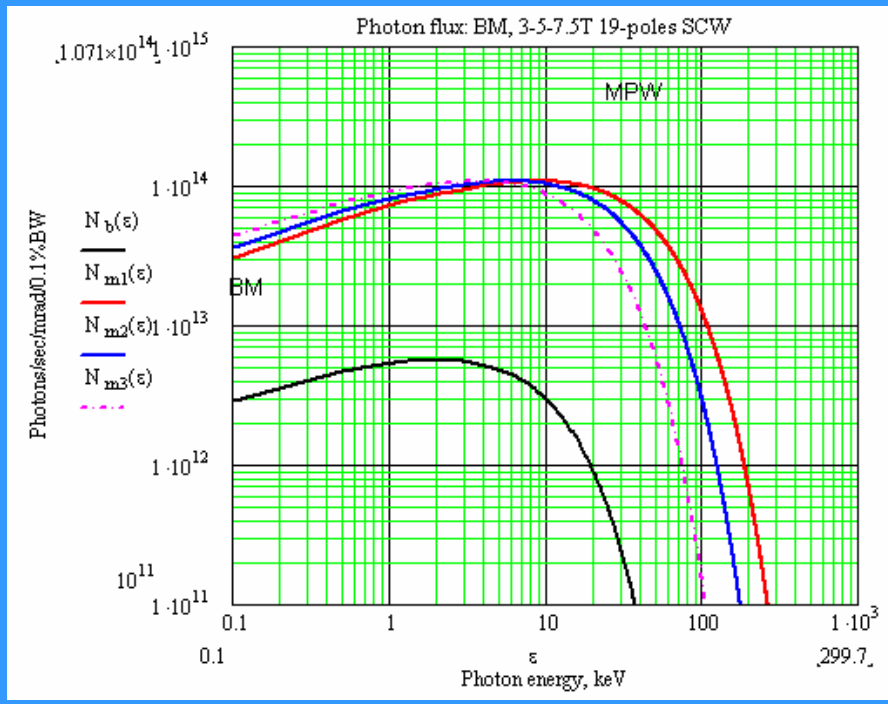
Flux = (10^{14}-10^{12}) ph/s/0.1%BW

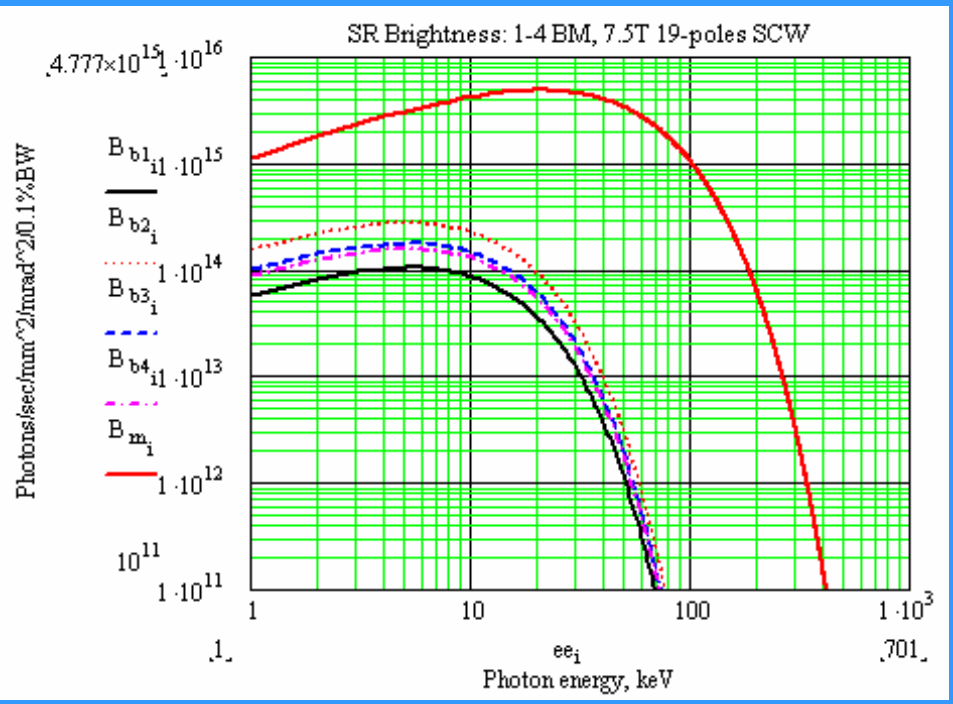
Eph = 5 - 200 keV .

Θ_x max = $\pm$ 23.5 mrad

Ptot (100 mA) = 36.5 kW

Spectral flux and brightness of synchrotron radiation from 7.5 T SCW & 1.7 T BM. E=2.5 GeV, I=0.1A

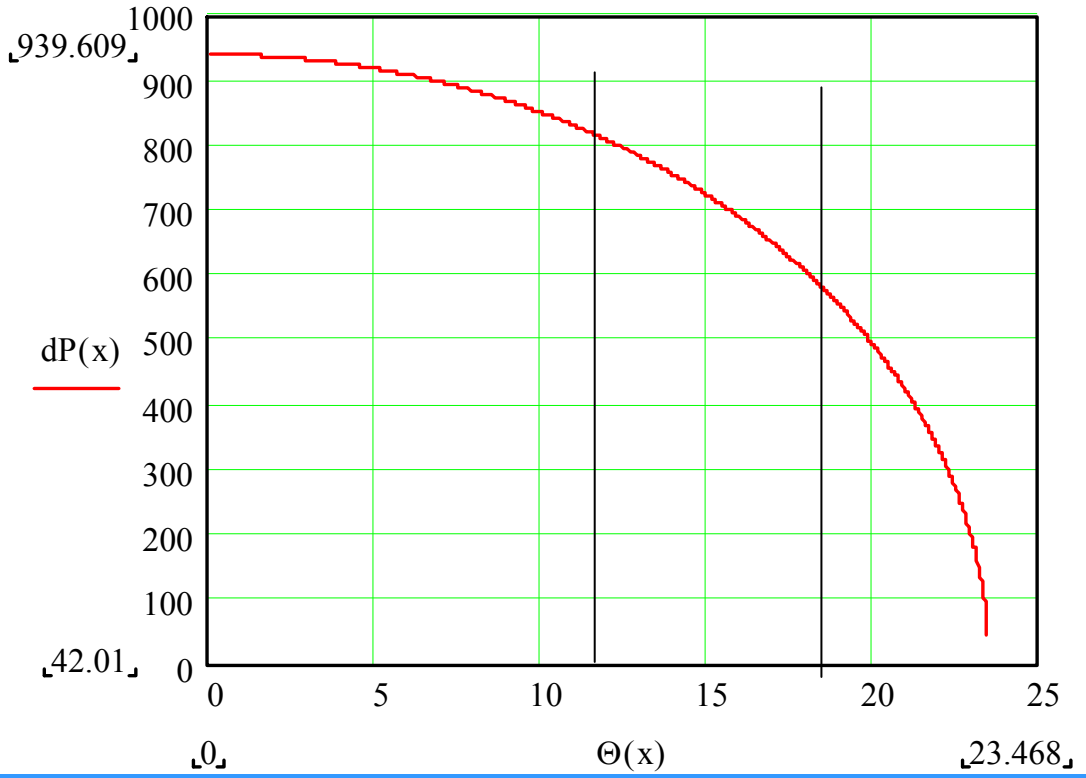




Angular density of SR power from 19-pole SCW of SIBERIA-2 as a function of horizontal angle E=2.5 ГэВ, I=0.1A, B=7.5 T.

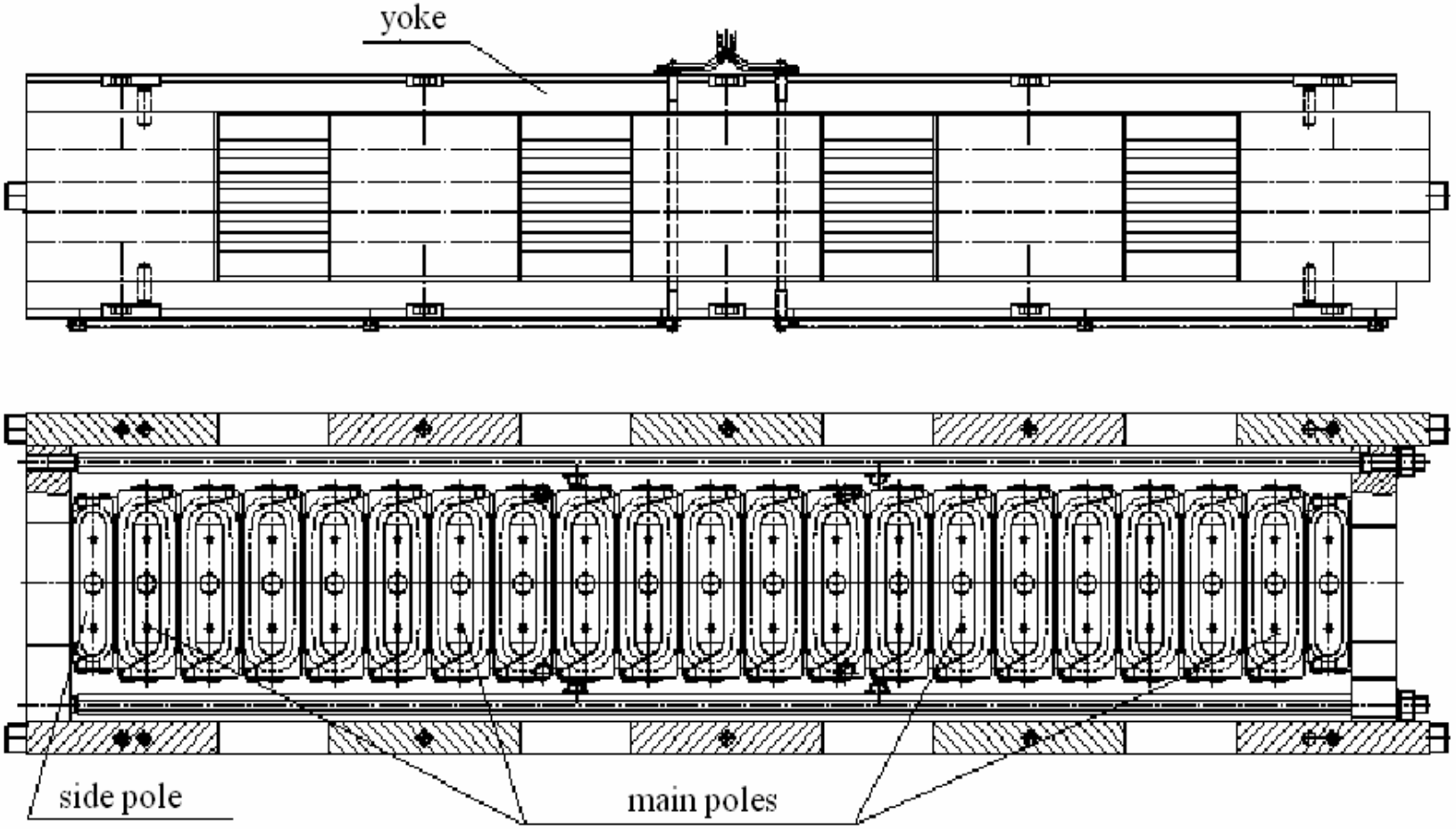
$$\frac{dP}{d\Theta}\left[\frac{W}{mrad}\right] = 4.22 \cdot E^3\,[GeV] \cdot B_m\,[T] \cdot I[A] \cdot \sqrt{1-(\Theta/\Theta_m)^2} \cdot N_{poles}$$

W/mrad

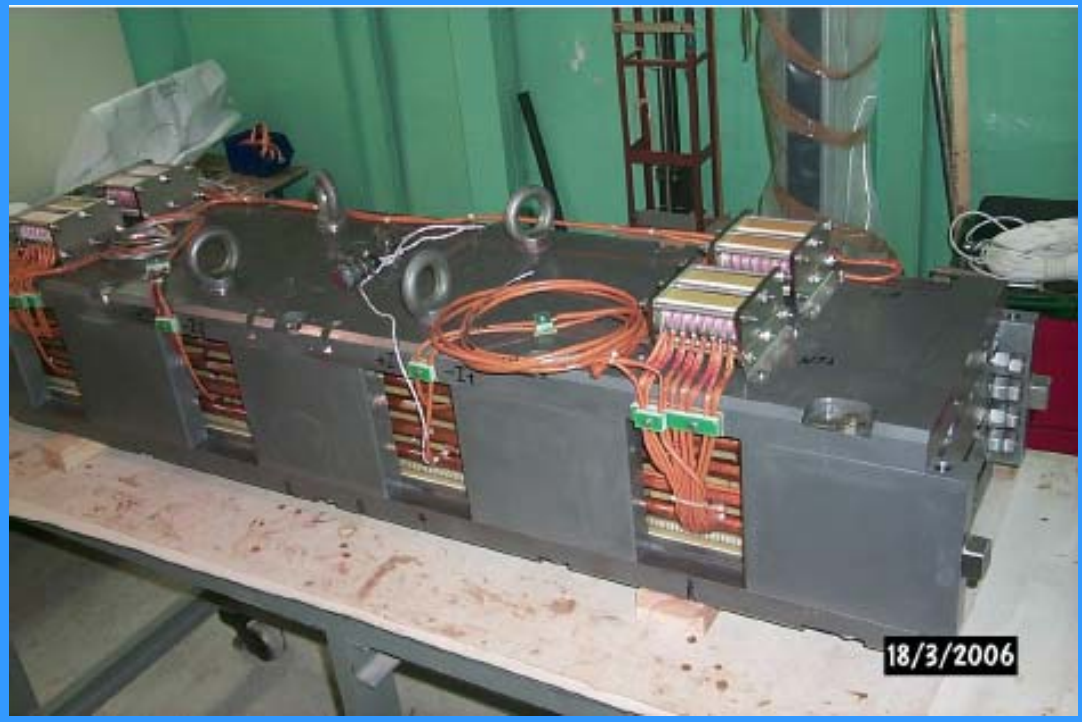


mrad

Magnet system of the wiggler-1



Magnet system of the wiggler-2

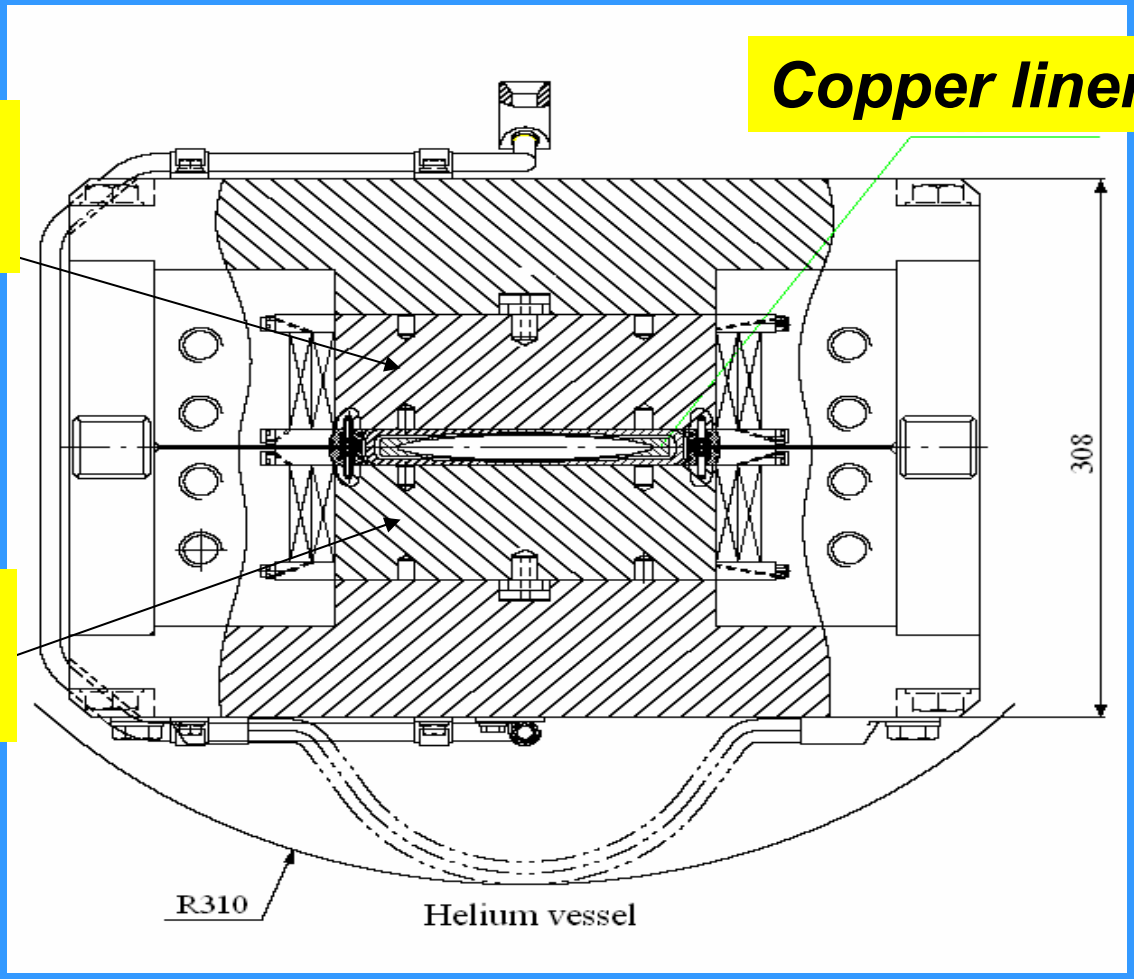


Pole with
coil after
thermo-hardening

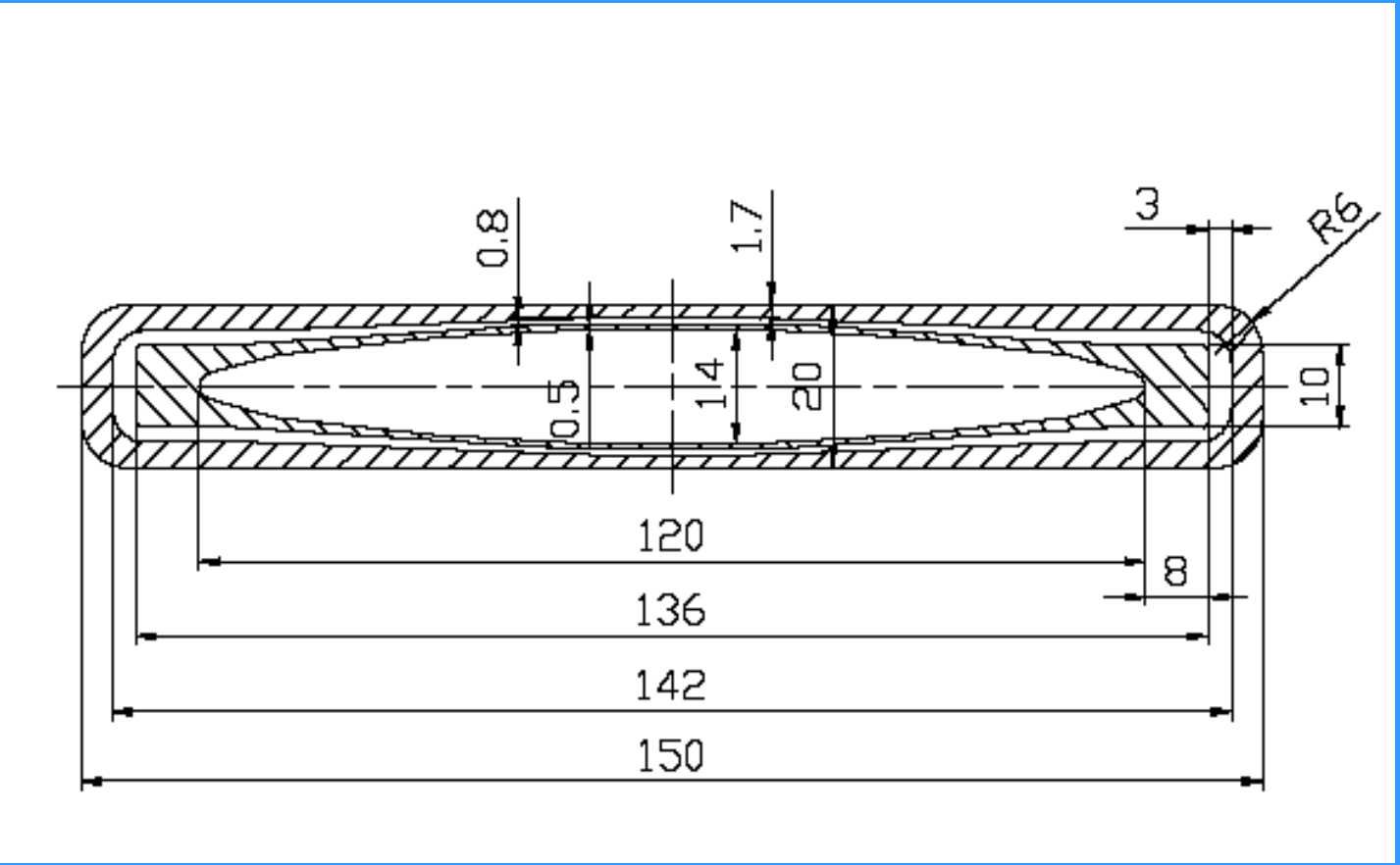
Wiggler pole cross-section

Upper pole array

Lower pole array

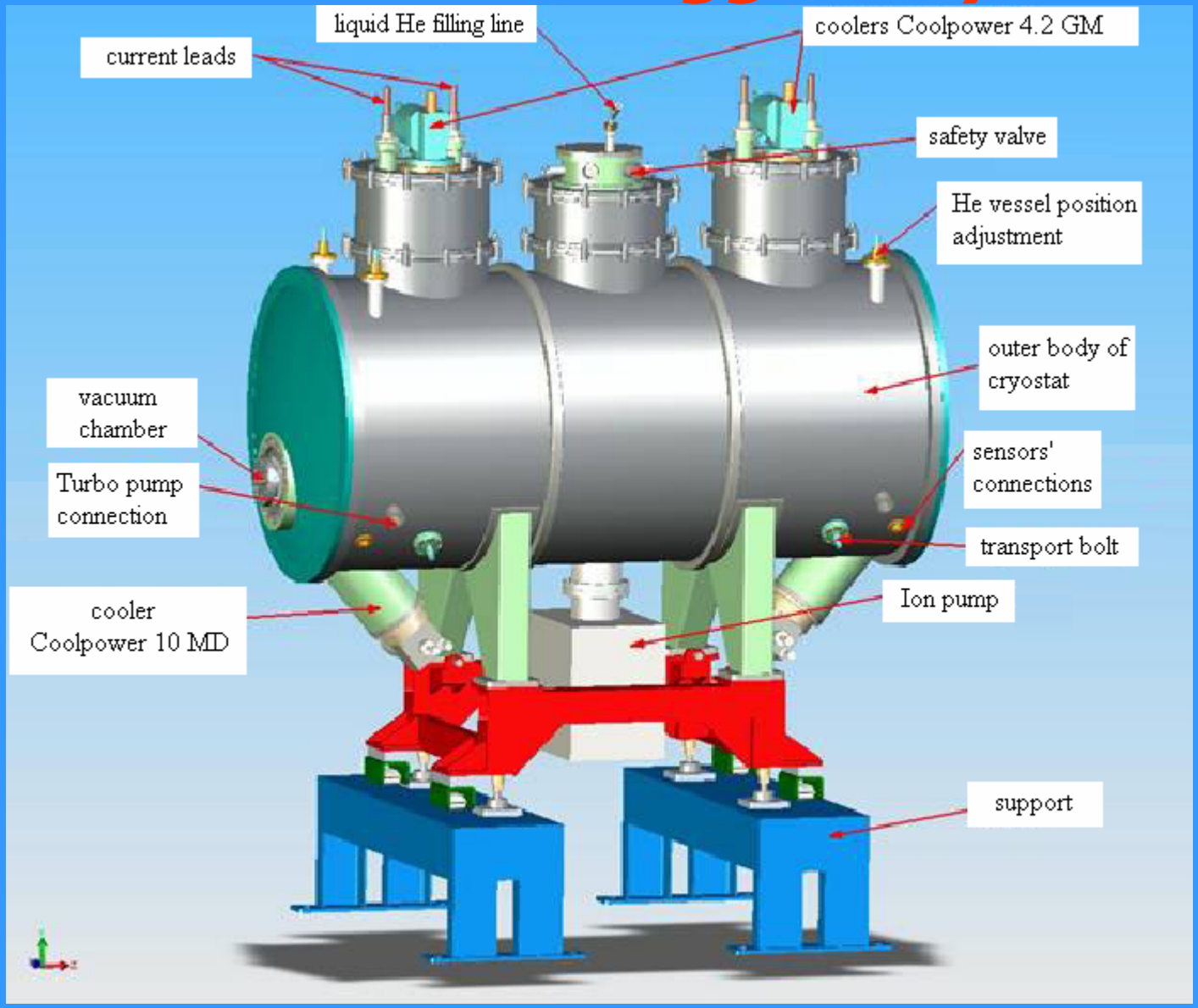


Vacuum chamber cross-section

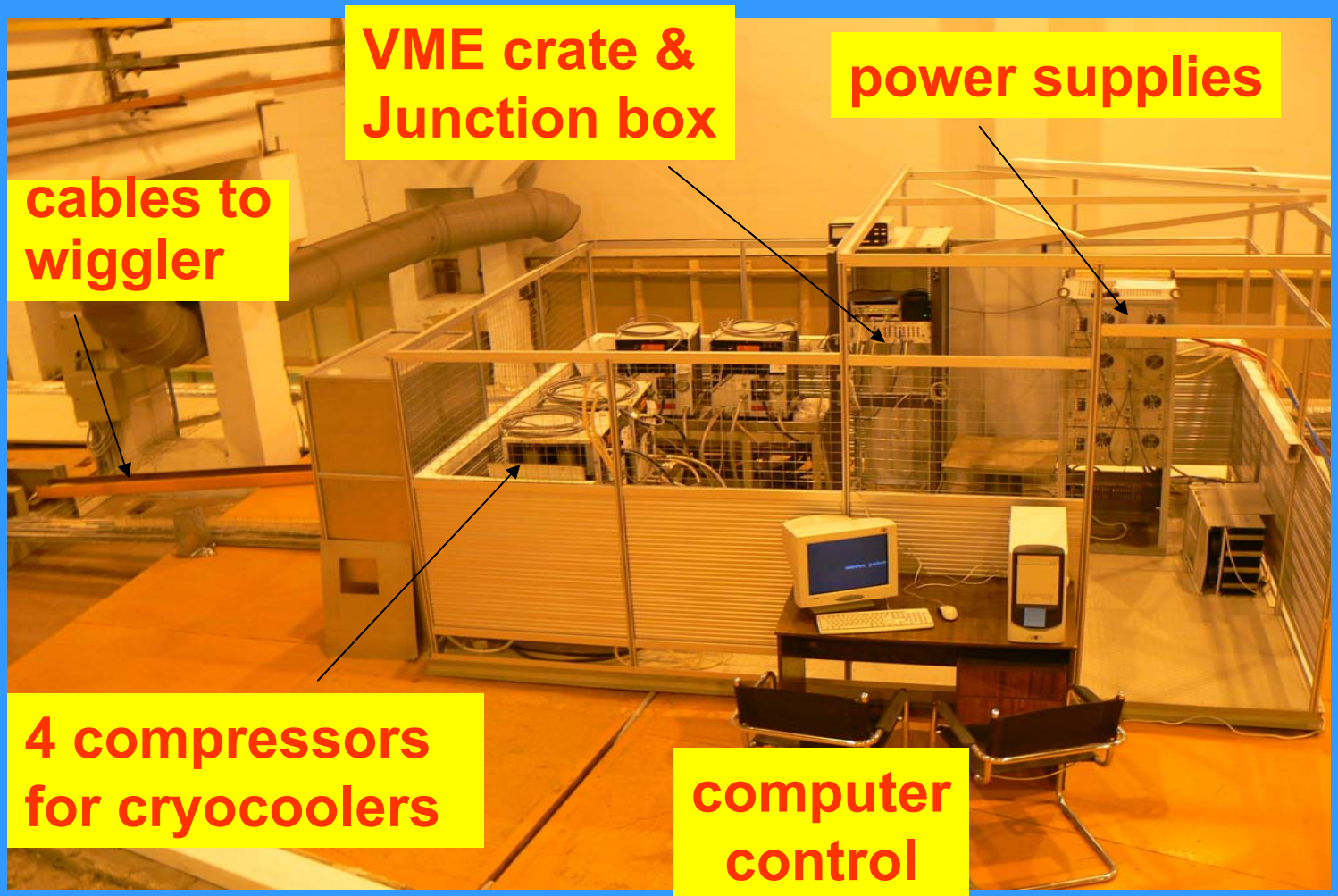


20 K copper liner inside 4.2 K stainless steel vacuum chamber

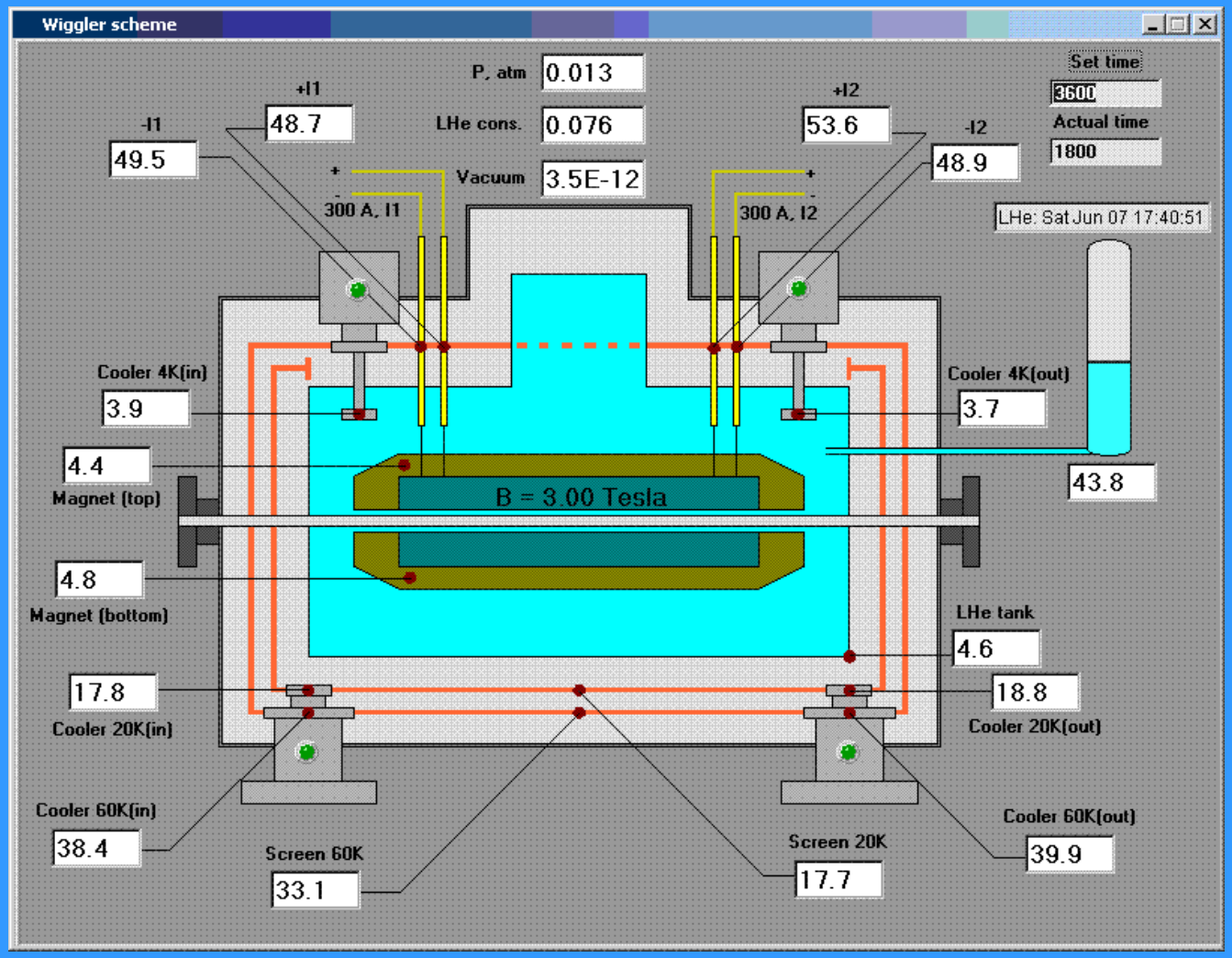
General view of wiggler cryostat



Wiggler equipment on the roof of SIBERIA-2 shielding



Wiggler scheme with sensors (program interface)

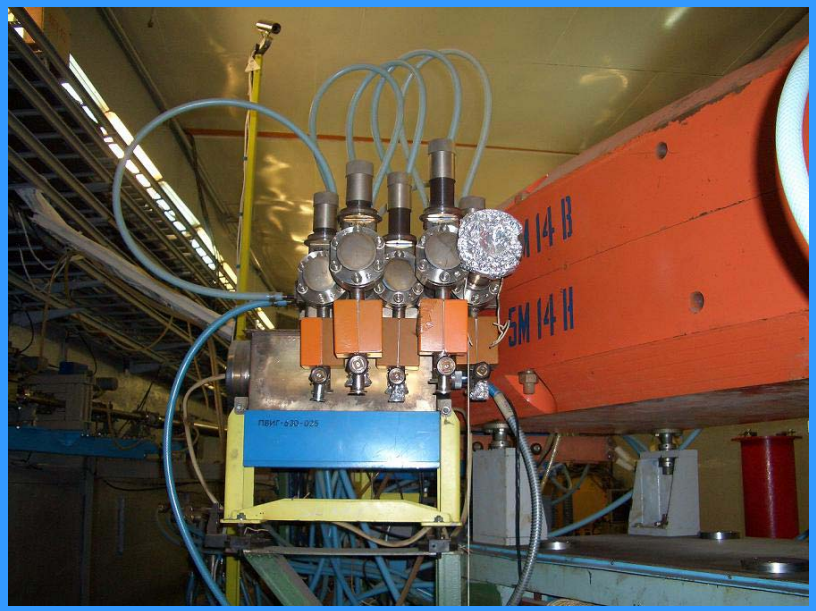


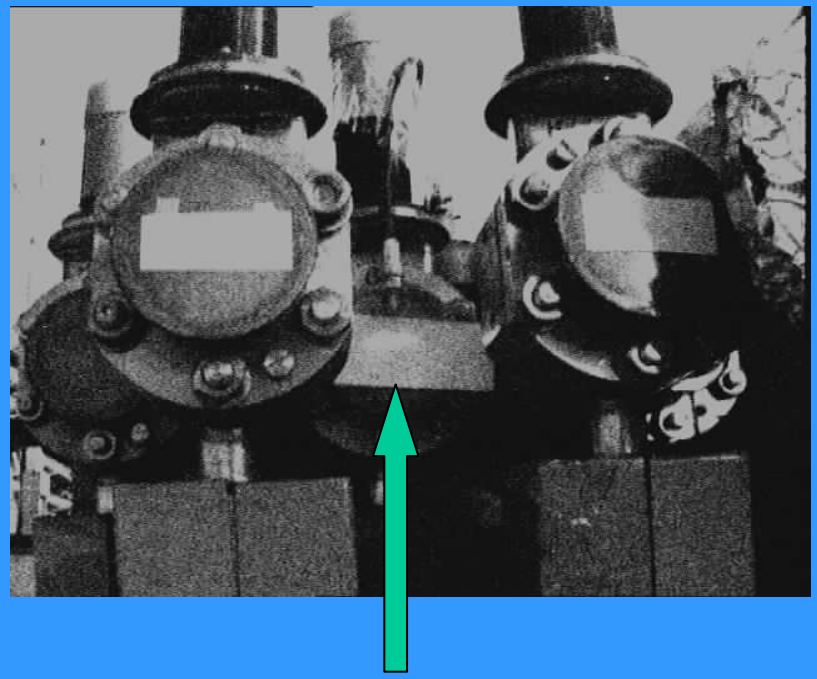
First radiation from superconducting wiggler

(7 June 2008)

B=3 T, Ee=2.5 GeV, Ie=25 мА

SR beam: λc=1Å°, P=1.46 kW, Θmax=9.4 mrad



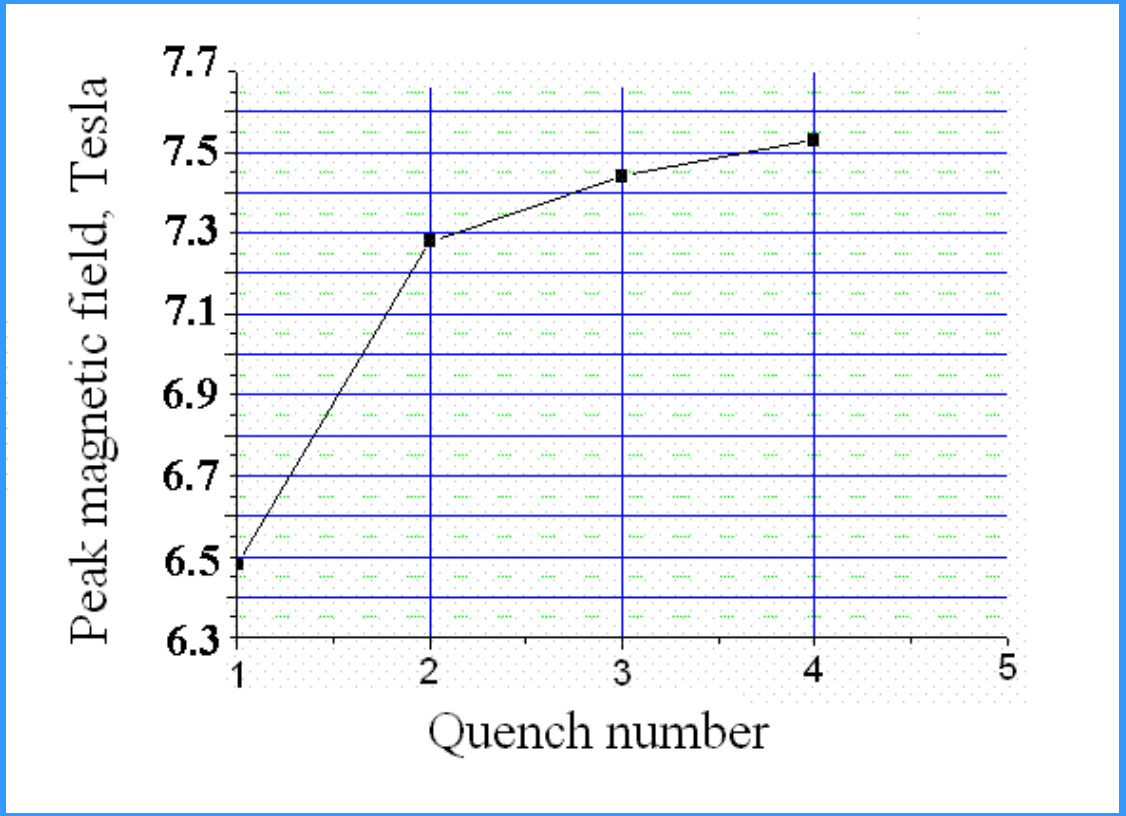


Radiation on luminescent screen

Wiggler influence on general beam parameters of SIBERIA-2 (theory)

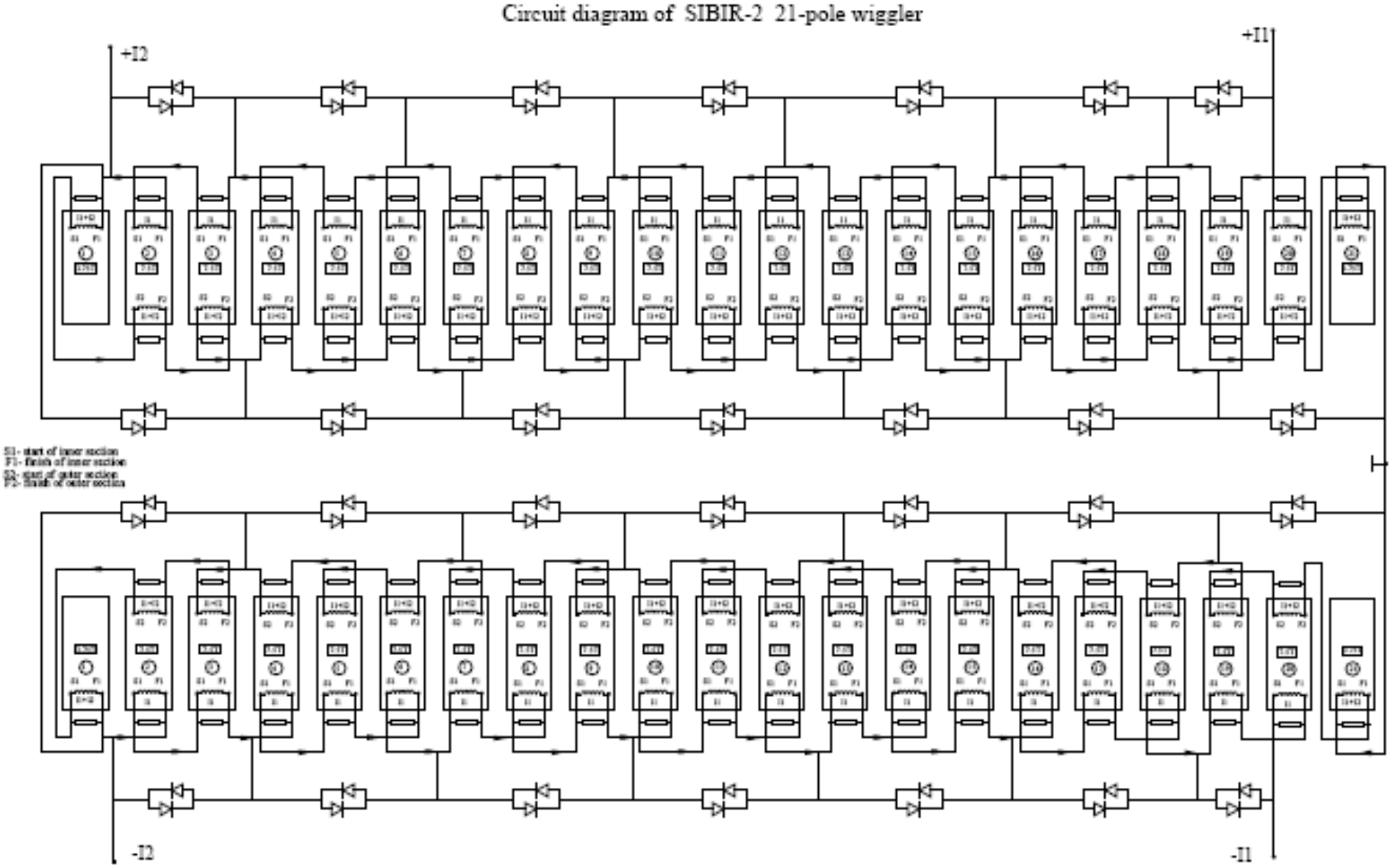
Parameters	Without wiggler	With wiggler 7.5 T
Energy	2.5 GeV	2.5 GeV
Horizontal emittance	***98 nm·rad***	***64.7 nm·rad***
Betatron tune shifts, $\Delta Q_{x,z}$	–	0, 0.05
Radiation loss per turn	***685 keV***	***1041 keV***
Orbit compaction factor	0.01036	0.01036
Energy dispertion, σ_E/E	***0.000953***	***0.00133***
Damping times: τ_x, τ_z, τ_s	3.15, 3.02, 1.48 ms	2.05, 1.99, 0.98 ms
RF-voltage amplitude	1.2 MV (current value)	1.61 MV (for the same energy

Stand testing
History of magnet quenches

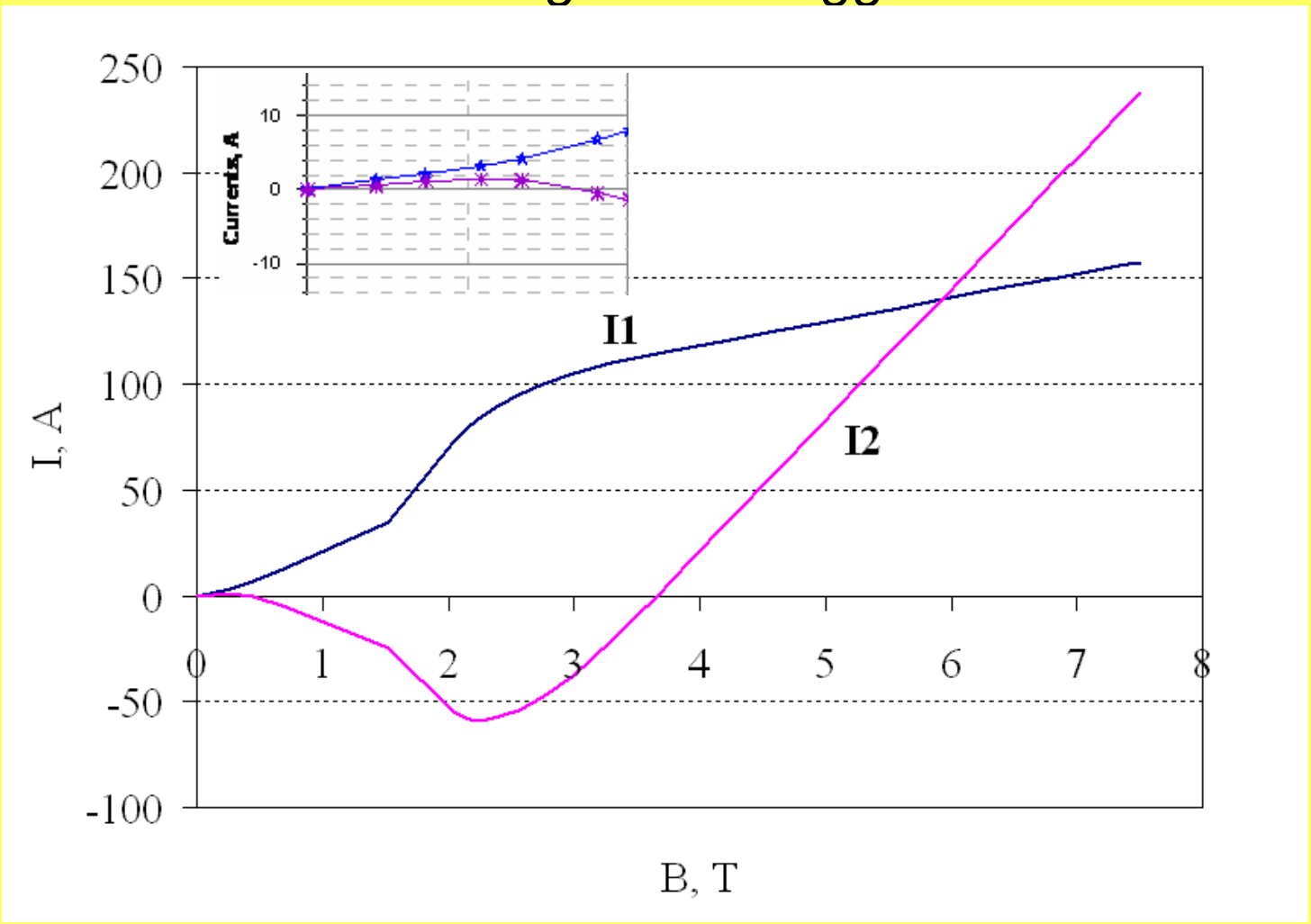


Liquid He consumption:
On stand close to zero at B=(0-7.5)T;
On storage ring = 0.066-0.09 l/hour at B=(0-3)T

Circuit diagram of SIBERIA-2 21-pole wiggler



Power supply currents I1 and I2 as a function of peak magnetic field B after compensation of field integrals on wiggler axis



Wiggler operation algorithm (June 2008)

- ***Storage ring at injection energy 450 MeV. Wiggler at 1.5 T. Betatron tunes and chromaticity correction.***
- ***Storing of electrons in SIBERIA-2. Injection efficiency has the same value like without field in the wiggler.***
- ***Energy ramping process from 450 MeV up to 2.5 GeV.***
- ***Increasing of the wiggler field from 1.5 T to 3 T. It takes approximately 4 minutes. Horizontal orbit changes are less than 0.5 mm. Vertical orbit is stable. Betatron tune changes are less than 0.01.***

Vertical betatron tune shifts due to wiggler

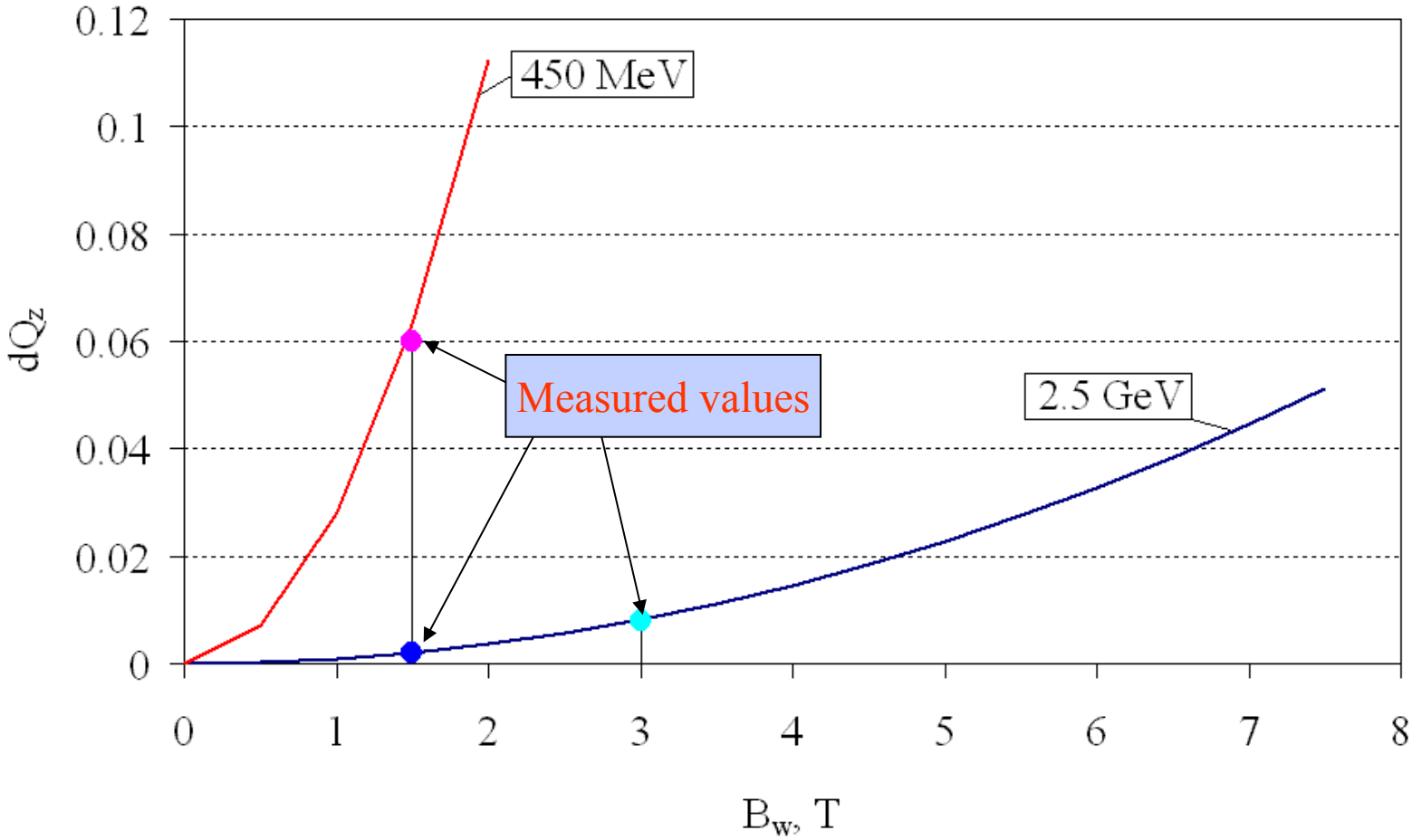
$$\Delta\nu_x = 0,$$

$$\Delta\nu_z \cong \frac{1}{4\pi}\left(\frac{1}{\rho_w}\right)^2 \frac{L_w}{2} <\beta_z>,$$

where $<\beta>$ - average value of β_z along the wiggler: $<\beta> = \beta_0 + \frac{L_w^2}{12\,\beta_0}$

β_0 is β-function value at the center of wiggler straight section,
L_w – wiggler length, $L_w = 0.5 \cdot N \cdot \lambda_w$,
ρ_w – minimum bending radius, $\rho_w = \frac{B\rho}{B_0}$
N – wiggler poles number,
λ_w – wiggler field period.
In our case $\beta_{0z} = 0.6$ m.

Vertical betatron tune shifts due to wiggler



Wiggler performance on SIBERIA-2 ring

- ***Vacuum performance** is acceptable. Beam lifetime is not determined by vacuum conditions in the wiggler straight section even when wiggler is warm.*
- ***Cryogenic performance** is not good. High liquid He consumption up to 2 liters per day. This value is not depend on electron beam current.*
- ***Vertical aperture** is less than design value 14 mm. Beam-based measurements gave 9.6 mm. But it has no influence on injection efficiency and lifetime at working energy.*
- ***Power supplies** now are unipolar. They allow operation only in the range between 0 and 3.5 T. Also they provide very low speed of extraction of electric energy from the wiggler (hours to decrease field from 7.5 T to zero).*

Nearest tasks to solve "wiggler problem"

- ***1.** Commissioning of the wiggler at maximum magnetic field*
- **1.1 High accurate geodesy.**
- **1.2. Codes for wiggler – storage ring SIBERIA-2 joint operation in different mode.**
- **1.3. Understanding of large liquid He consumption. Now – 2 l/day…**

- ***2. Study and compensation of wiggler influence on e-beam***
- **2.1. Optimal operation regimes excluding electron beam losses.**
- **2.2. The increase of injection efficiency, now it is smaller in a factor ~ 1.5 than early.**
- **2.3. The increase of e-beam lifetime in case of total SR power growing.**
- **2.4. Control angle-space location of high power SR beam from wiggler with a help of correctors of SIBERIA-2.**

- ***3. Safety extraction of intense and power SR beam through the 3-ports front-end absorber***
- **3.1. Upgrade of vacuum chamber between wiggler and front-end, installation additional SR absorbers;**
- **3.2. The creation of high power density absorber of SR.**
- **3.3. Installation of new 3 wiggler beam lines in tunnel of the ring and experimental hall.**

Results

- 7.5 superconducting wiggler was installed on SIBERIA-2 ring. First but not last!
- First synchrotron radiation was observed.
- New algorithm of SIBERIA-2 operation with wiggler was created. Best results was 25 mA electron current at 2.5 GeV with 3 T peak field.
- High level of liquid He consumption was found.
- We need new bipolar power supplies allowing fast field decreasing.

Thank You
for attention!