SAD Project: Objectives, Tech. Description, Status, Cost Assessment

Third SAD/YALINA Steering Committee Meeting

SAD Project Objectives

- Coupling all major components of ADS;
- Core design, safety assessment, licensing;
- k_{eff} control and monitoring;
- Shielding from high energy neutrons;
- Experiments on core neutronics, reactivity feedbacks, transmutation reaction rates

SAD Technical Description (participating organizations)

ISTC project #2267 was started at Nov 2003

- **JINR - leading organization, scientific supervisor;**
- **GSPI - the general designer;**
- **NIKIET – subcritical blanket and target designer;**
- **VNIINM - the developer of a fuel element;**
- **IA "Mayak" - manufacturer of the fuel;**

About 180 people at present are working on project

SAD Technical Description (foreign collaborators)

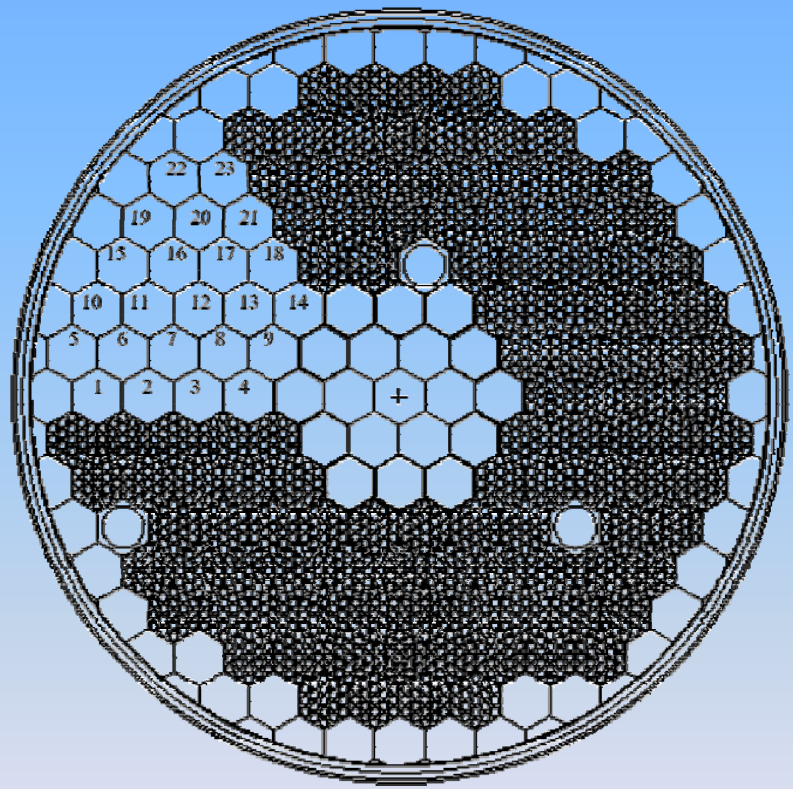
- Forschungszentrum Karlsruhe - FZK, Institut für Reaktorsicherheit, Dr. Cornelis Broeders;
- Kungliga Tekniska Högskolan - KTH, Nuclear and Reactor Physics, Dr. Waclaw Gudowski;
- Centro de Investigaciones Energéticas Medioambientales y Technologies - CIEMAT , Dr. Enrique Miguel Gonzalez Romero;
- Commissariat a l'Energie Atomique - CEA, Cadarache, Dr. Frederic Mellier;

Basic Data

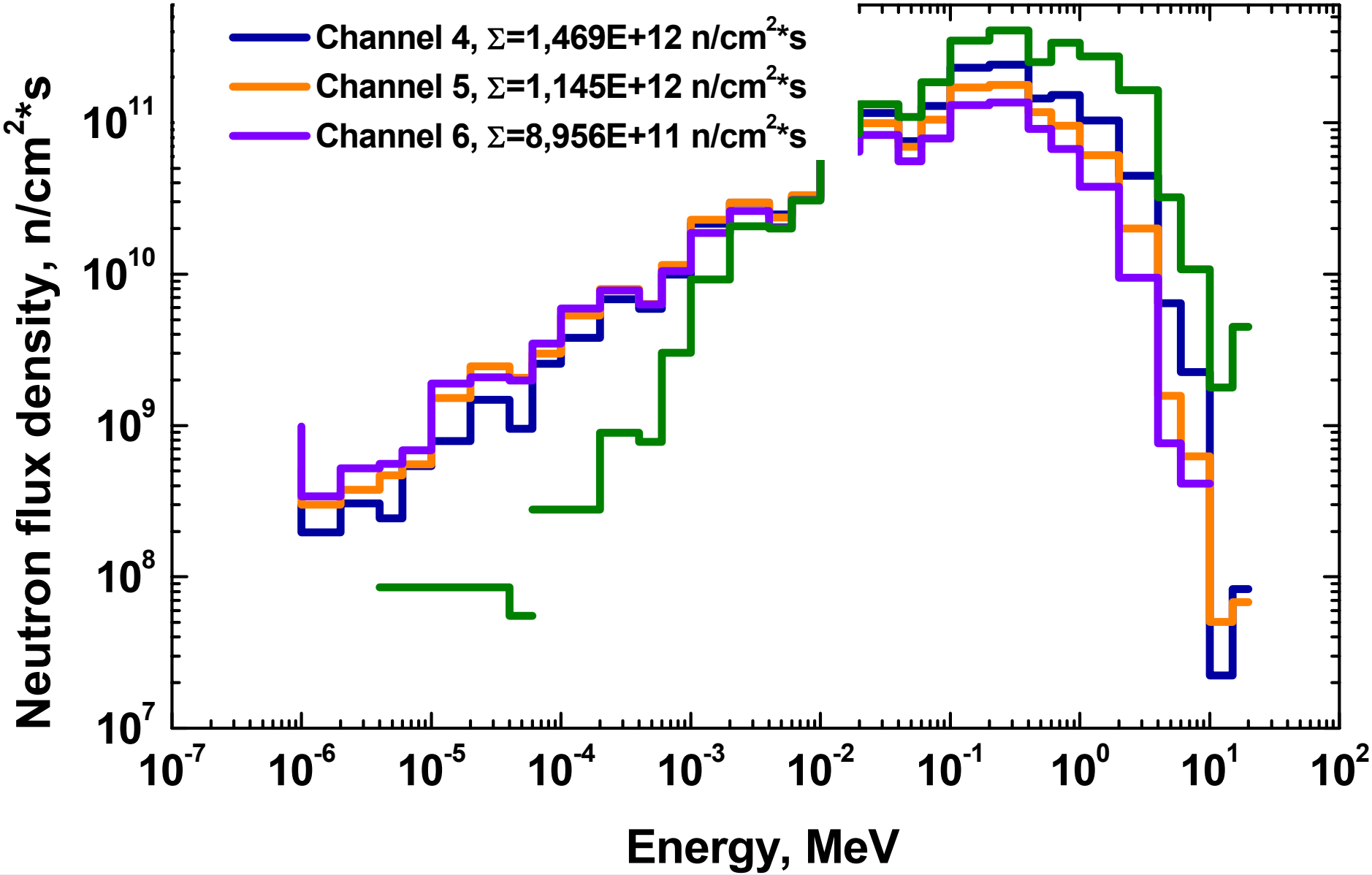
k_{eff}	~0,95
Fuel loading	< 420 kg
Fission power	27,6 kW
Cooling	air
Core	
Coolant flow rate, G	~ 0,6 kg/s
velocity, v	10 m/s
Presure, P *(inlet)*	0,12-0,135 MPa
Temperature, T *(inlet, outlet)*	50/96 ºC
Target (Pb)	
Coolant flow rate, G	~ 0,0067 kg/s
Velocity, v	50 m/s
Pressure, P *(inlet)*	0,12-0,135 MPa
Temperature, T *(inlet, outlet)*	50/125 ºC

Subcritical Blanket/calculations

Number of cells for FAs	141
Number of loaded FAs	134
Number of loaded Pb prisms	7
fuel loading (UO_2-PuO_2)	396,9 kg
density of fuel	10,2 g/cm^3
PuO_2 content in fuel	29,5 % (w.)
U enrichment	0,7 % (^{235}U)
Height of fuel	58 cm



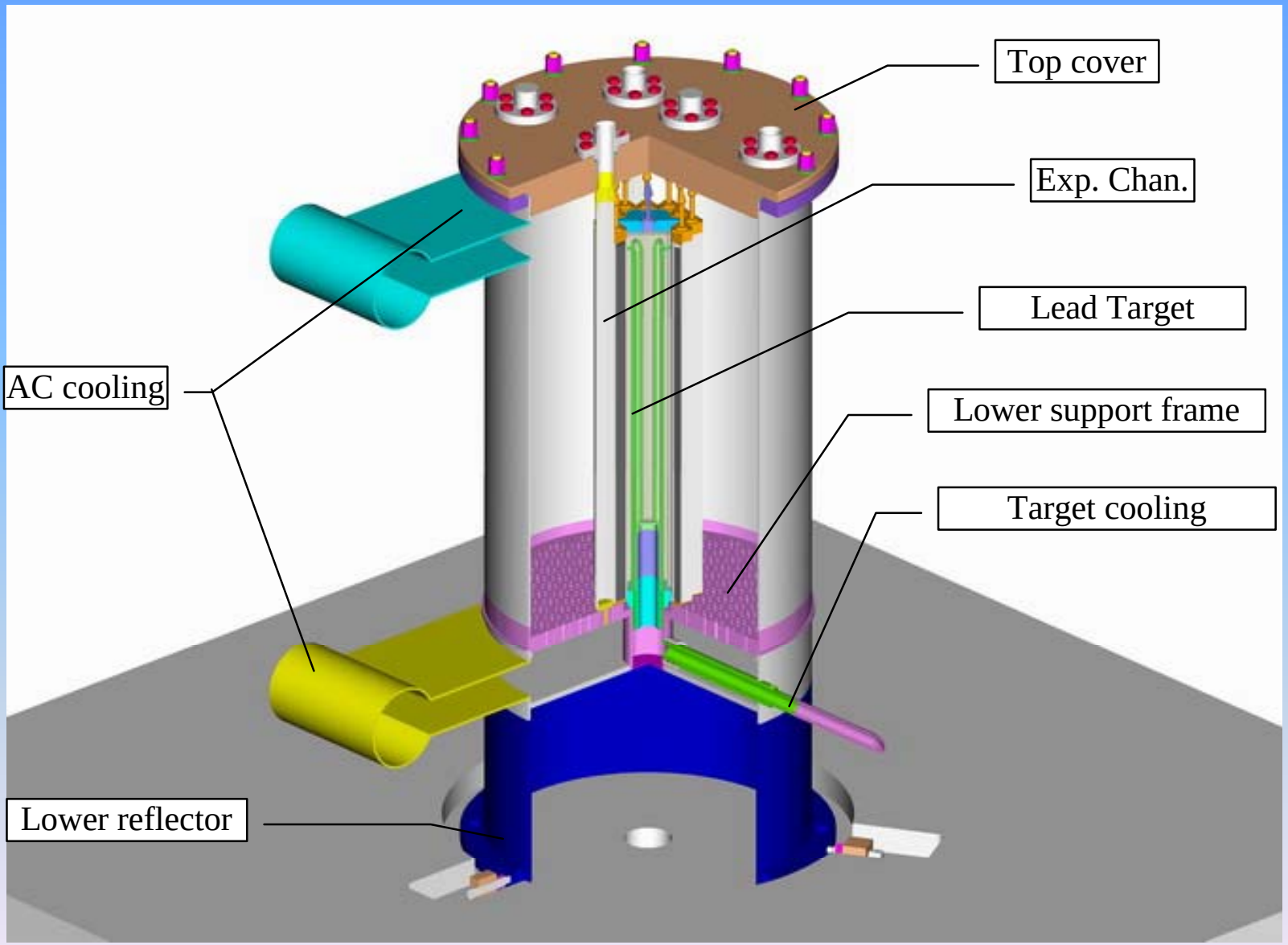
Subcritical Blanket/calculations



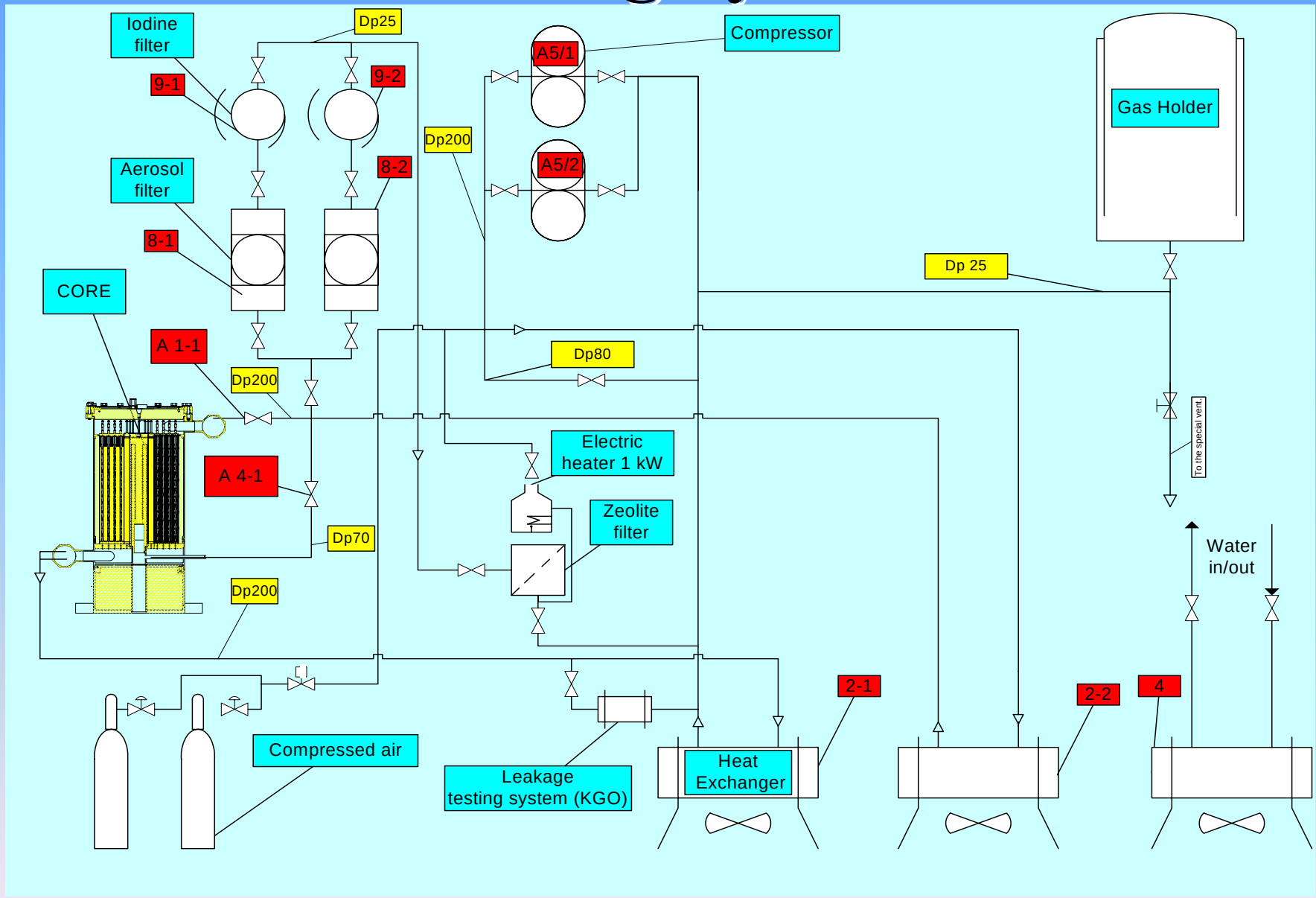
Subcritical Blanket/ neutronics

Calculated K_{eff}	0.9515
Neutron lifetime	$2.4 \cdot 10^{-5}$ s
Fission power	**27.6 kW**
Averaged neutron flux	**$1.7 \cdot 10^{12}$ 1/(cm^2·s)**
Peak factor of heat generation (height)	1.21
Heat generation in SAD parts:	
Fuel	25.96 kW
Target (neutron and photon from fissions)	97.3 W
Core cladding	204.3 W
Side Pb reflector	565.4 W
B_4C	204.6 W
Concrete	771.1 W
Pu decay	~250 W
Fuel	
Max power density	**18 W/cm^3**
Max flux of fast neutrons (E> 0,1 MeV)	$2.4 \cdot 10^{12}$ 1/(cm^2·s)
Max fluence of fast neutrons	$8.0 \cdot 10^{19}$ 1/cm^2

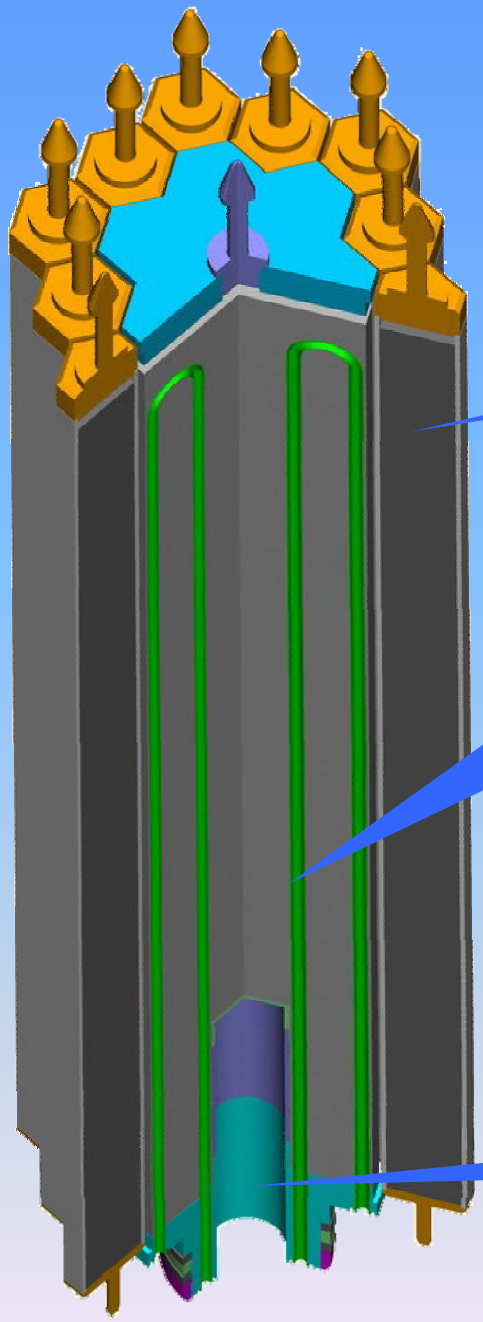
Subcritical Blanket/design



Cooling System



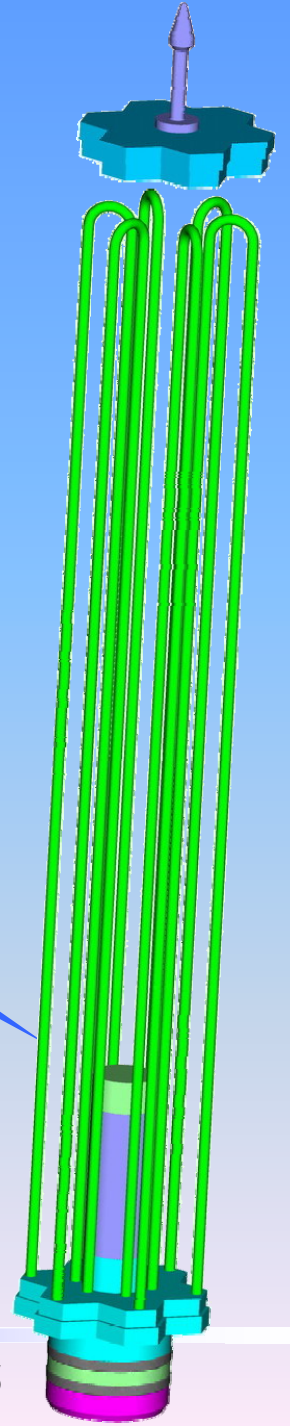
Target/design



Lead Prisms

Air Channels

Beam Input



Target/neutronics

Proton beam	
Energy	660 MeV
Beam power	1 kW
Target	
neutron generation	12.95 n/p
total neutron leakage from target	12.73 n/p
side neutron leakage from target	12.22 n/p
total energy of leakage neutrons	103.2 MeV/p
total heat generation	840 W
neutron source for blanket	$1.143 \cdot 10^{14}$ n/s

Phasotron Accelerator

Charged particles accelerated	Protons
Accelerator Type (linac, circular)	Circular (Phasotron)
Main accelerator sections and type of structures	180degree Dee
Source type	Internal, PIG type
Source Extraction voltage	Dee RF Voltage,40kV
RF system (amplifier characteristics)	Autogenerator,18.6-14.4MHz, 300kW
Magnet system (type, size, rigidity, homogeneity)	H-type, 6m pole diameter, 4spiral magnetic field 1.2T(r=0m) 1.63T(r=2.7m) average field, 0.3T(r=2.7m) 4^{th} harmonic
Magnet Power Supply characteristics (current, stability, ramping, …)	4000A, 0.05%stability
Total Power consumption	700kW
Cooling System	Distilled water cooling

Phasotron Accelerator

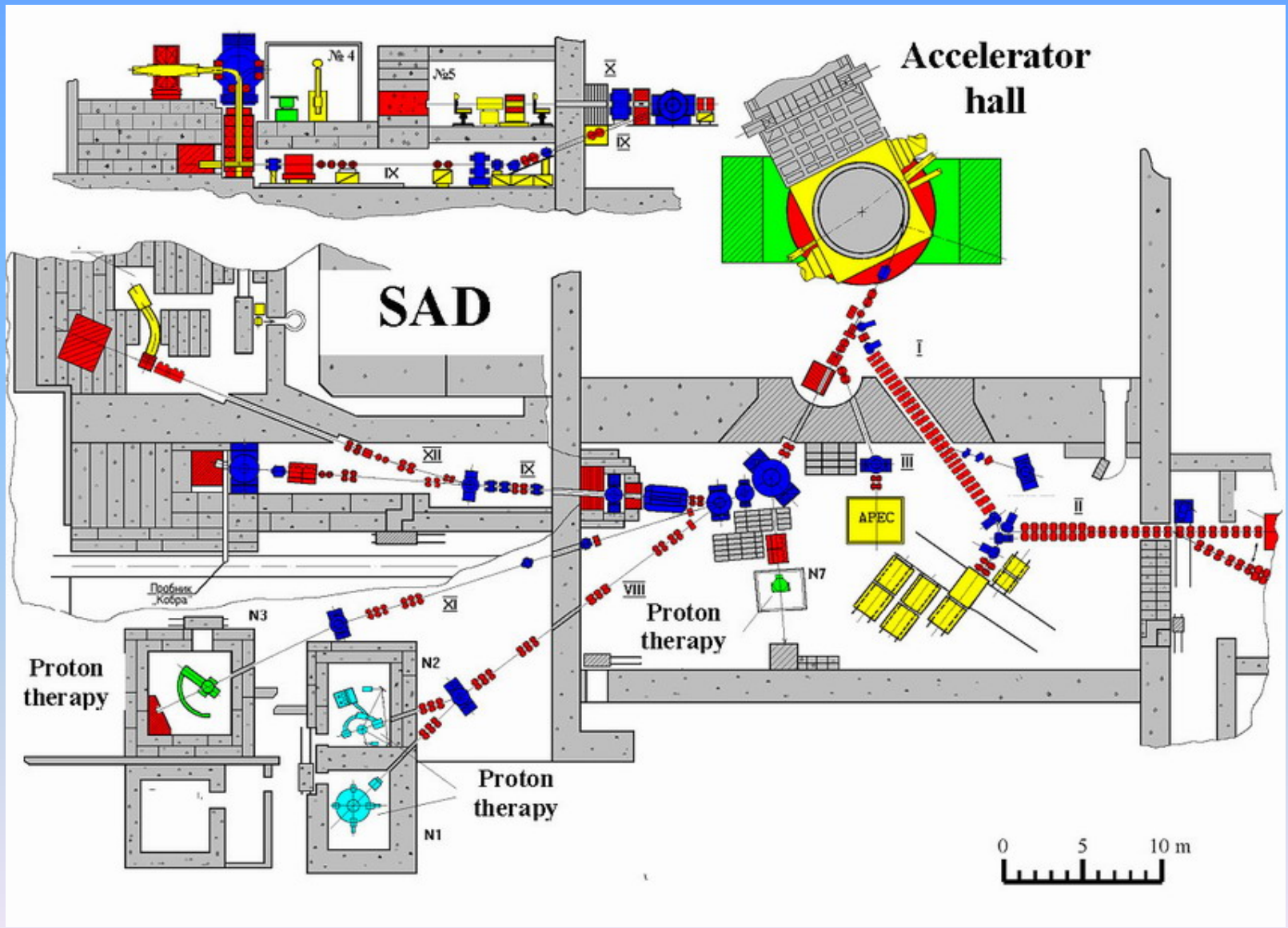
Beam Characteristics	
RF structure (RF frequency, phase width)	14.4MHz, 50degree
Macro pulse structure (filling of RF pulses)	250Hz rate, 20 mks FWHM
Long duration Beam Pulse characteristics (duty cycle, …)	0.5%duty
Final beam energy	659MeV
Beam energy spread and stability	3.1MeV
Final beam intensity (average, peak)	3.2 mkA average, about 1mA peak
Beam intensity stability	About 2%
Beam emittance at the high energy end	5.1pi*cm*mrad (horizontal), 3.4pi*cm*mrad (vertical)

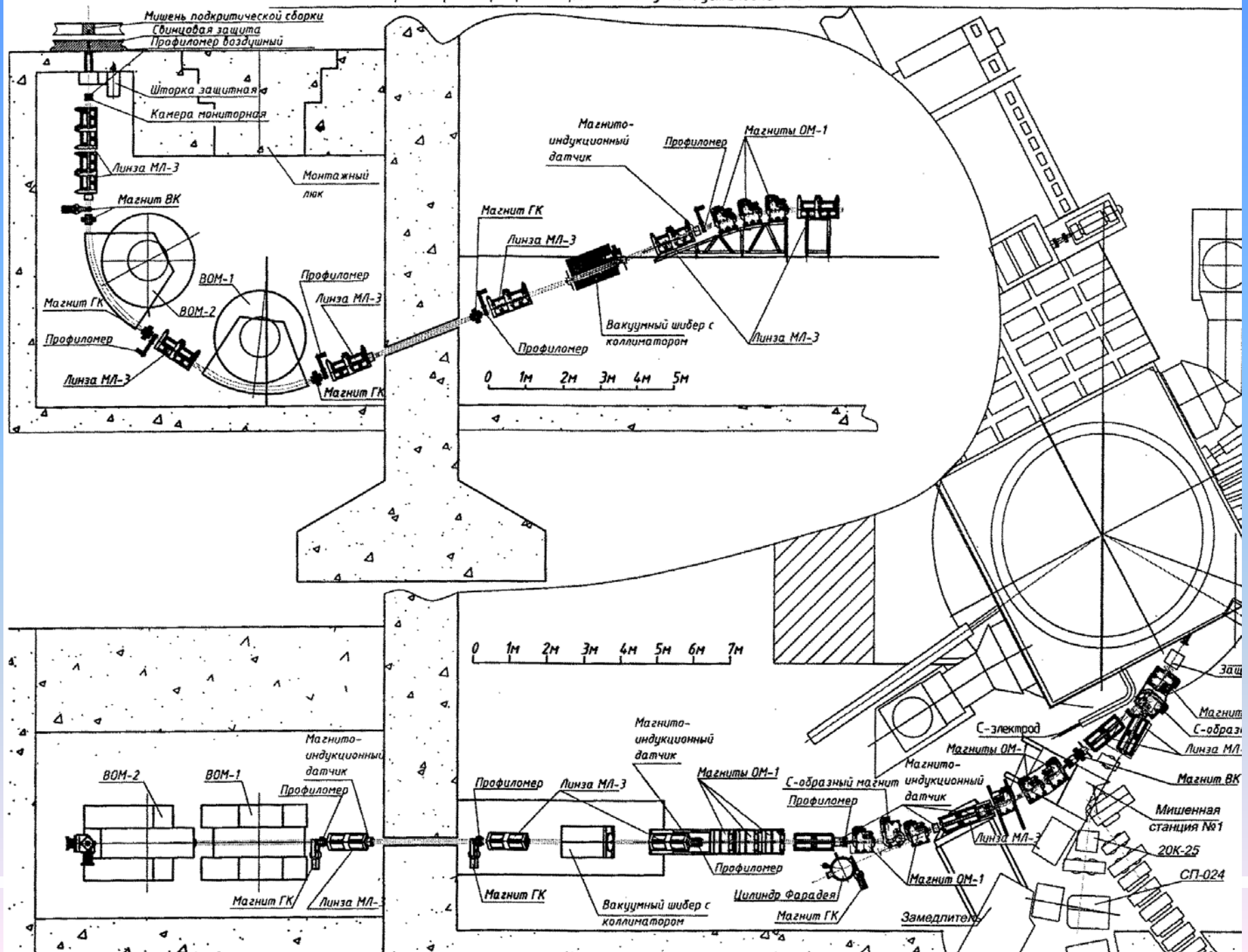
Possibility to shorten the pulse width down to 1 mks is under investigation

Phasotron Accelerator

Phasotron Accelerator

Phasotron Accelerator




Тракт транспортировки протонного пучка к установке SAD
Мишень подкритической сборки
Свинцовая защита
Профиломер воздушный
Шторка защитная
Камера мониторная
Монтажный люк
Линза МЛ-3
Магнит ВК
ВОМ-1
ВОМ-2
Магнит ГК
Профиломер
Линза МЛ-3
Магнито-индукционный датчик
Профиломер
Магниты ОМ-1
Магнит ГК
Линза МЛ-3
Вакуумный шибер с коллиматором
Профиломер
Линза МЛ-3
0 1м 2м 3м 4м 5м
0 1м 2м 3м 4м 5м 6м 7м
С-электрод
Магниты ОМ-
Магнито-индукционный датчик
Магнит ВК
Мишенная станция №1
20К-25
СП-024
Замедлитель
Магнито-индукционный датчик
ВОМ-2
ВОМ-1
Профиломер
Магнит ГК
Профиломер
Линза МЛ-3
Магниты ОМ-1
Профиломер
Магнит ГК
Вакуумный шибер с коллиматором
С-образный магнит
Профиломер
Магнито-индукционный датчик
Линза МЛ-3
Магнит ОМ-1
Цилиндр Фарадея
Магнит ГК

Initial data for SAD FE design

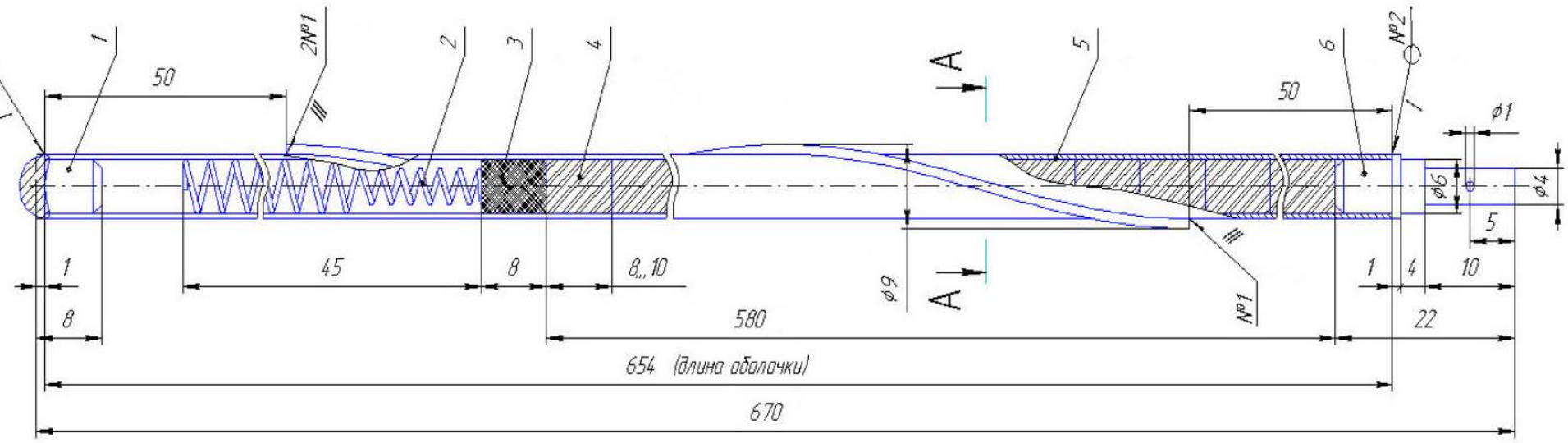
Operating Conditions

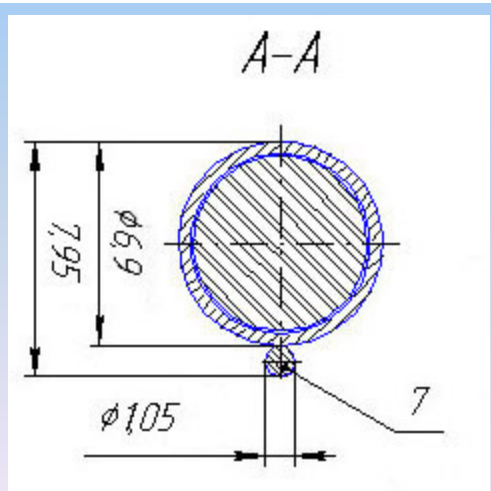
- Maximum Dose for Constructional Materials of Fuel Element – 0.25 dpa.
- Fuel Maximum Burn up – 0.1 % h.a.
- Maximum Linear Power of Fuel Element – 0.275 kW/sm.
- Maximum Temperature of Fuel Element Cladding - 150°C.
- Core Coolant - Dry, Dust-free Air.
- Maximum Coolant Temperature at Core Output - 125°C.
- Fixed Resource of Fuel Element for Operation of Installation at Nominal Power (27 kW) – 10000 h.
- Fixed Core Lifetime of Fuel Element - 10 years.

Processing Requirements for Fuel Element

- Uranium and Plutonium Feed Powders, which are used for BN-600 MOX Fuel Fabrication.
- Constructional Materials of Standard BN-600 Fuel Elements.
- MOX Fuel Pellets Fabrication at "MAYAK".
- Fuel Element Fabrication at "MAYAK".
- Fuel Element Quality Control by "MAYAK" Control Procedures and Equipment.
- Components Fabrication at MSZ JSC.

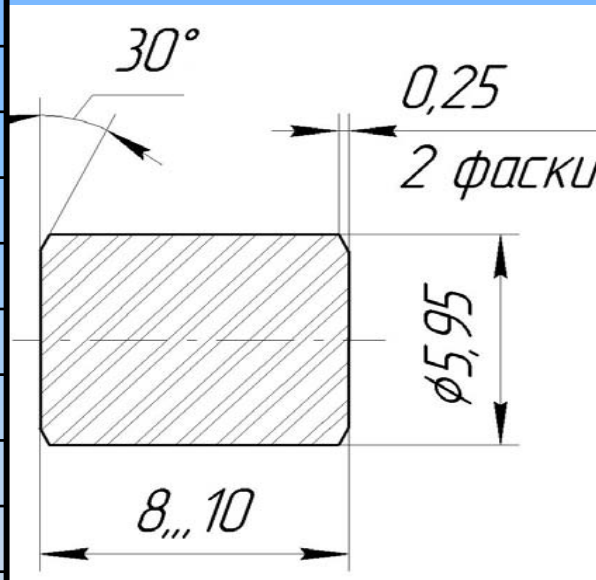
FE design


1
50
2№1
2
3
4
A
5
50
6
№2
1
ø1
ø6
ø4
5
1
45
8
8,,10
ø9
A
№1
1
4
10
8
580
22
654 (длина оболочки)
670


A–A
7,95
6,9ø
ø1,05
7

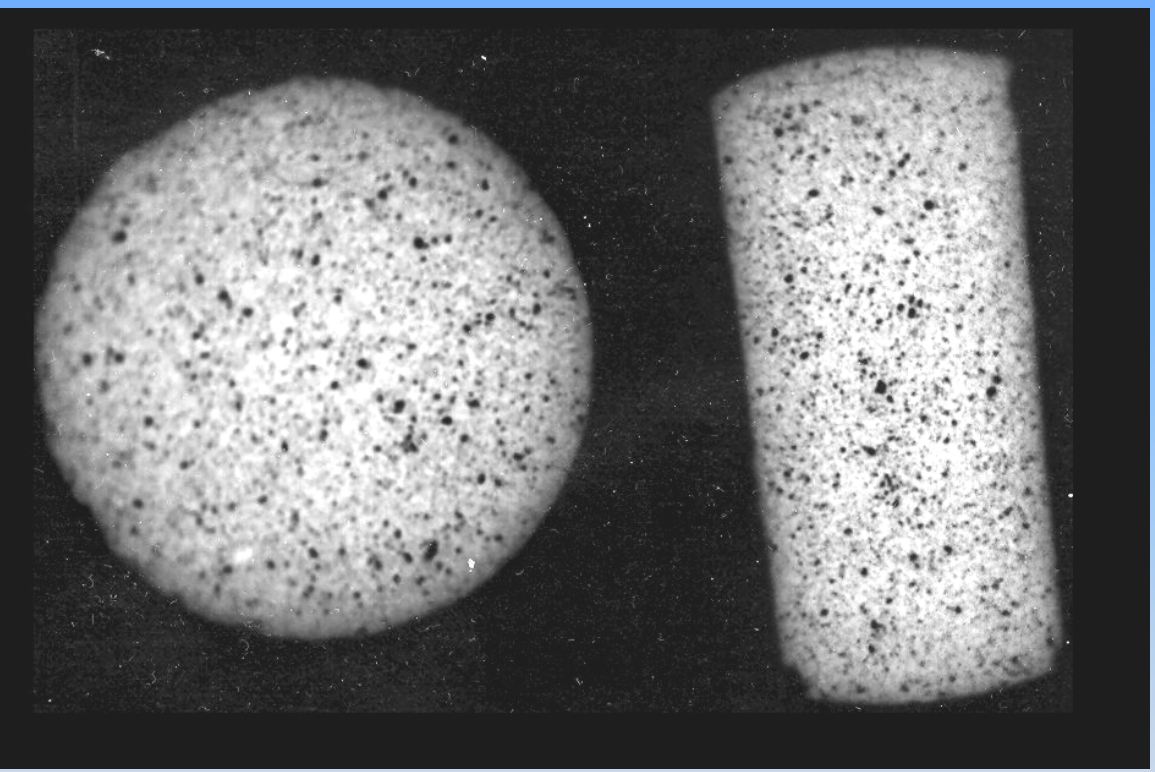
Fuel pellet

Mass share of U and Pu sum , %, not less	87.6
^{239}Pu conditional mass in Pu dioxide, %, not less	95.0
^{235}U conditional mass in U dioxide, % not more	0.7
Pu conditional mass share to U and Pu sum, %	30.0±0.3
Oxygen ratio	1.98
Density, g/sm^3	10.4±0.2
Impurities mass share, %, not more	
Aluminium	0.02
Calcium	0.02
Magnesium	0.02
Iron	0.03
Silicon	0.02
Nickel	0.02
Chromium	0.02
Nitrogen	0.01
Carbon	0.01
Fluorine + Chlorine	0.005
Grain size, µm, not more	70



Pellets parameters control

Pu distribution homogeneity study



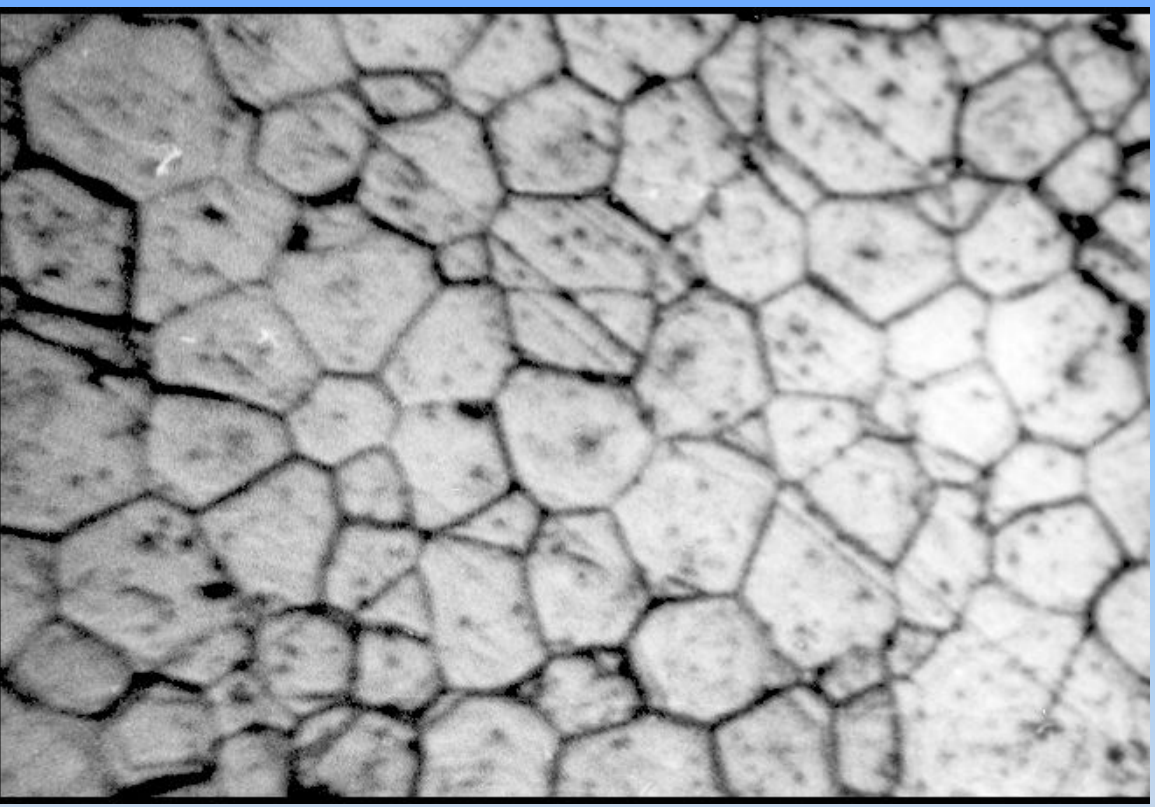
α-radiography

Pu zones less than 100 mkm in diameter

Pu zones area less than 10% of microsection area

No Pu zones observed here

Grain and pore dimensions

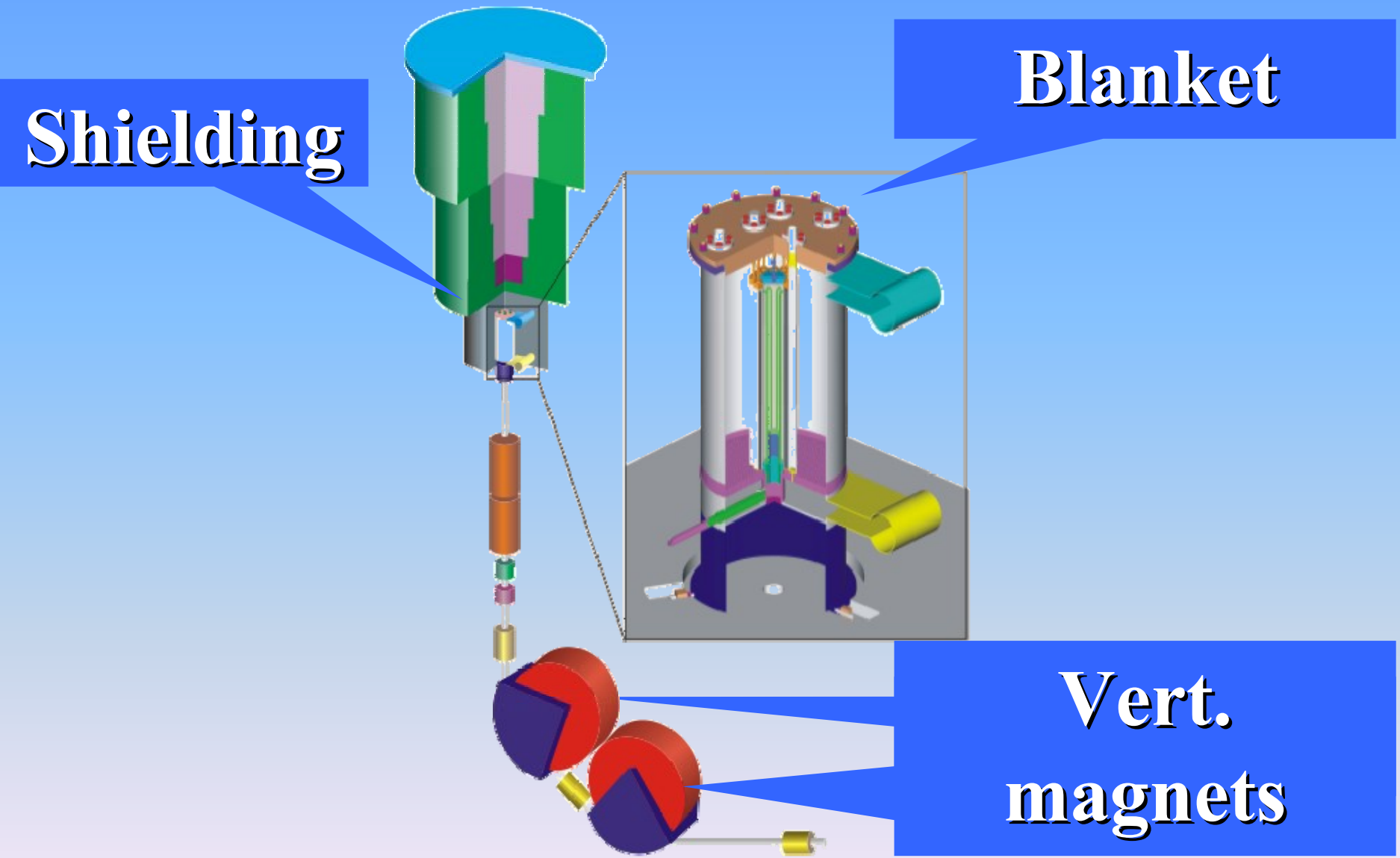


Microscopy study of the microsections processed in HNO_3 and HF acids

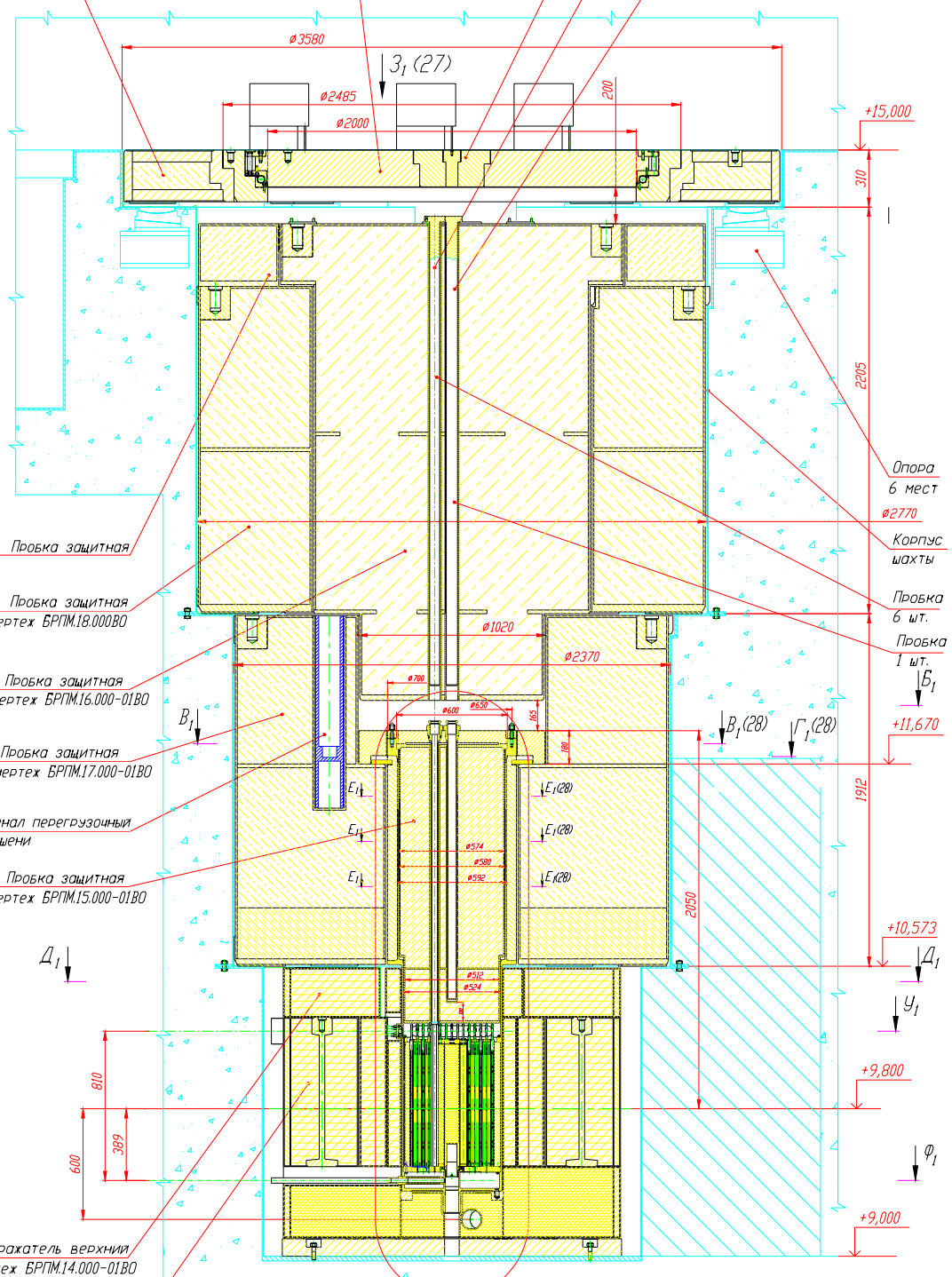
Pores diameter < 100 mkm and area less than 10% of microsection area

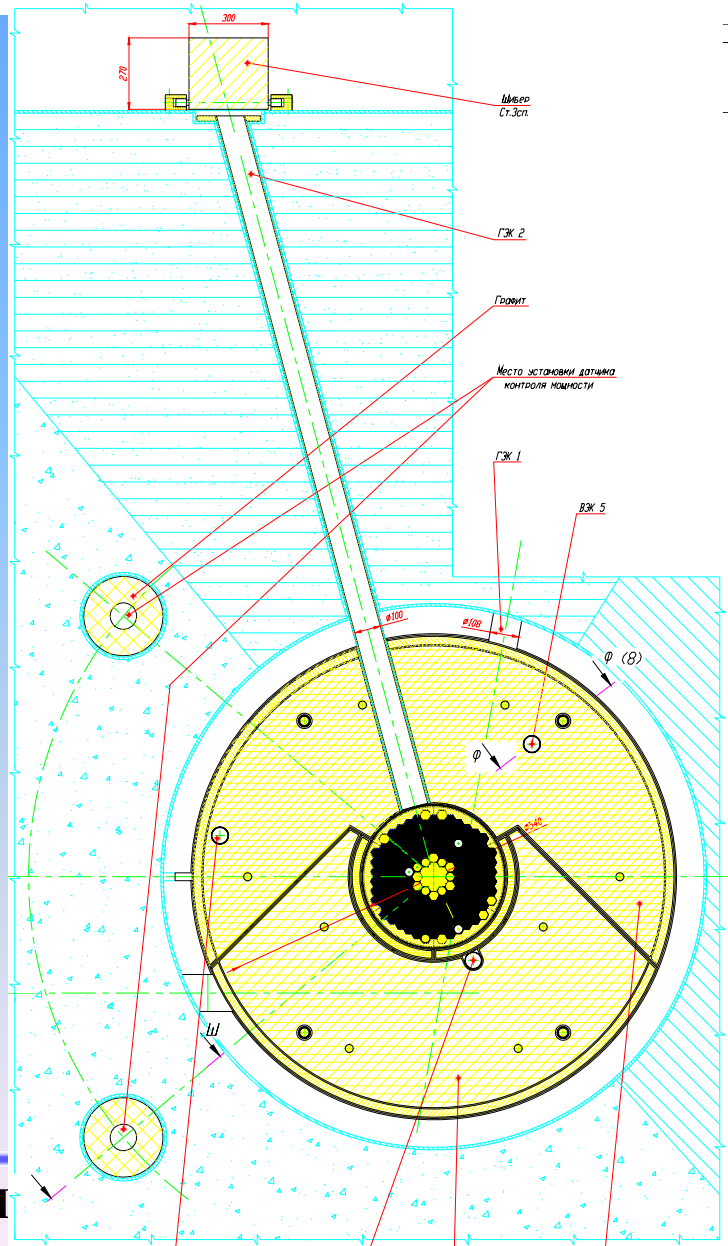
Grain diameter should be < 50 mkm (20-25 for that sample)

General Layout



General Layout





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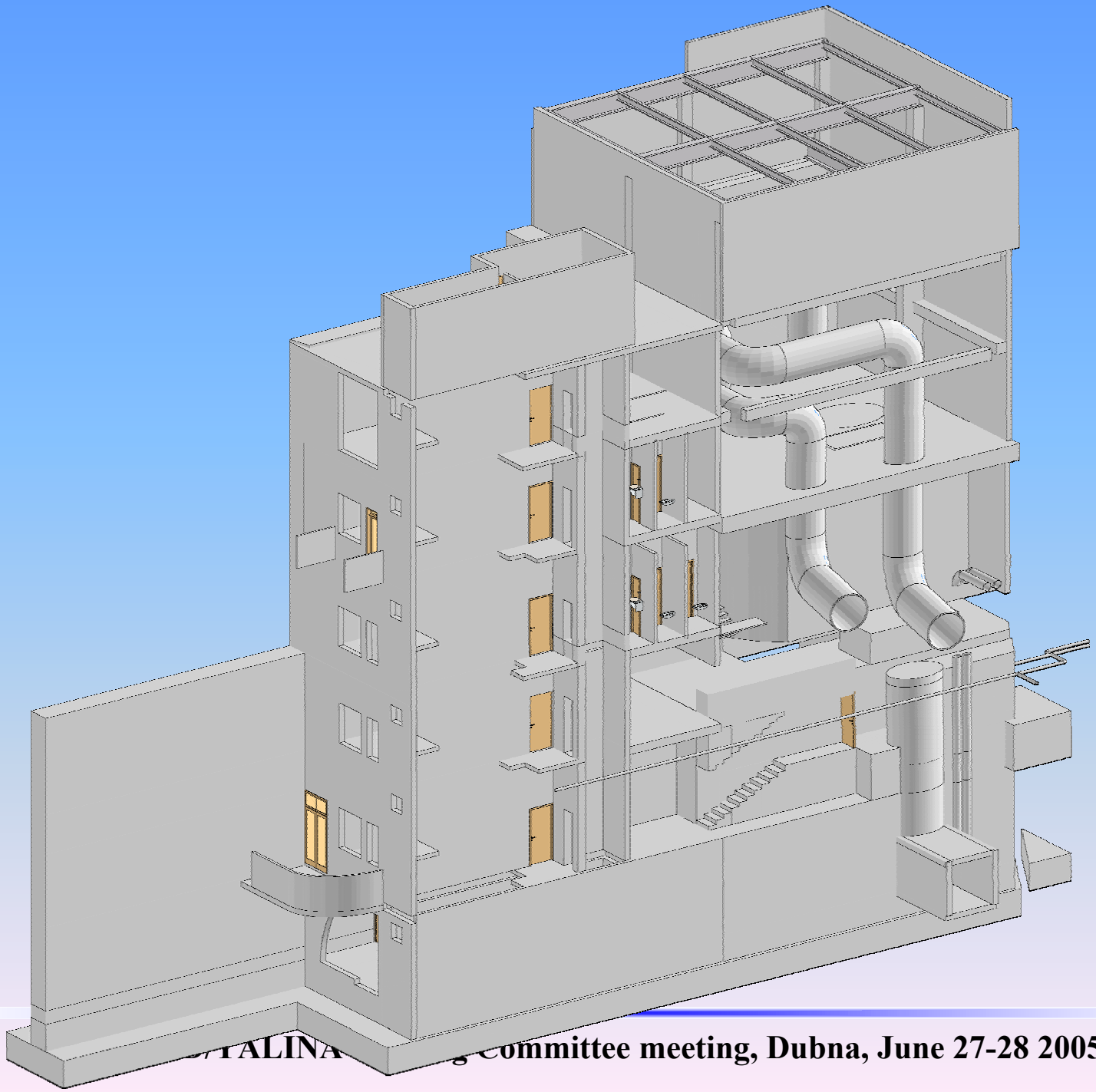
General Layout

Parameter	Value
Site area, m^2	350
Total area, m^2	950
Building volume, m^3	8300
Bulk concrete volume, m^3	1900
Steel shielding, ton	290
Bulk heavy concrete volume, m^3	25
Soil shielding volume, m^3	2000
Excavated soil volume, m^3	4000
Concrete retaining wall necessary to dismount, m^3	350

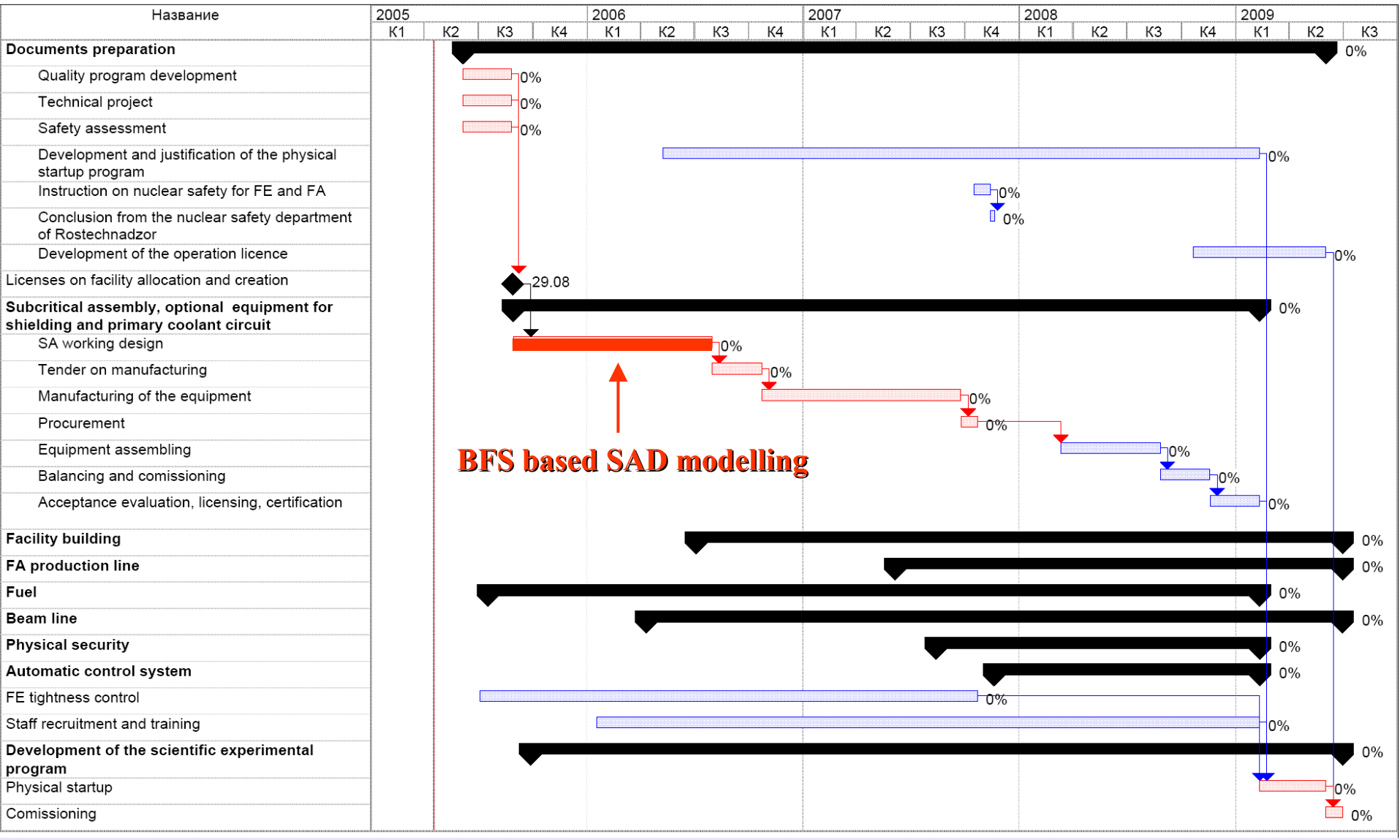


Project Status

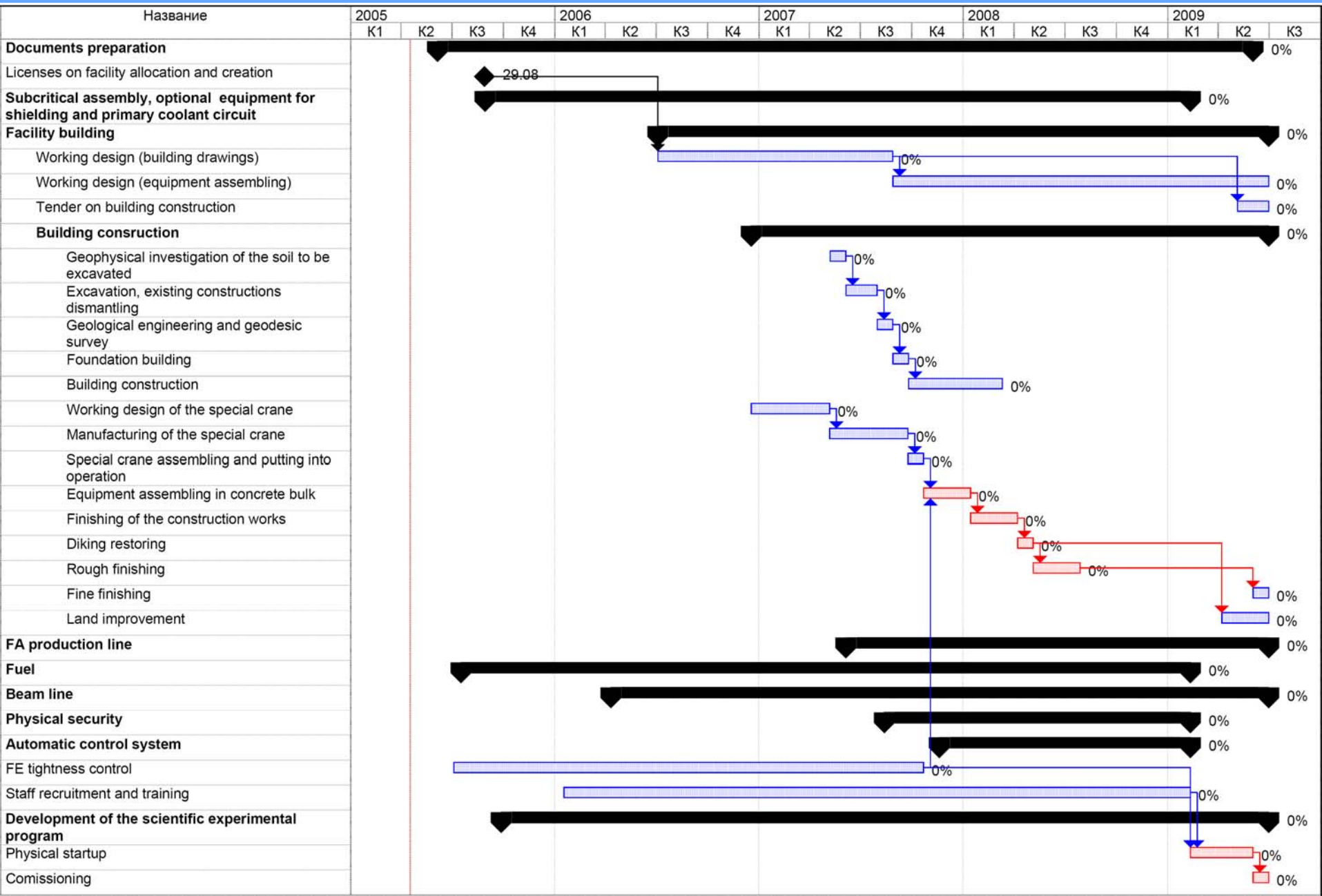
- Technical project of the subcritical blanket: **completed**;
- Technical project of the beam line: **completed**;
- Technical project of the fuel element: **completed**;
- Fuel pellets manufacturing technology: **developed**;
- Preproduction batch of the fuel pellets: **manufactured**;
- General engineering project: **completed**;

Licensing started some project documents already approved by Rostechnadzor (former Gosatomnadzor)

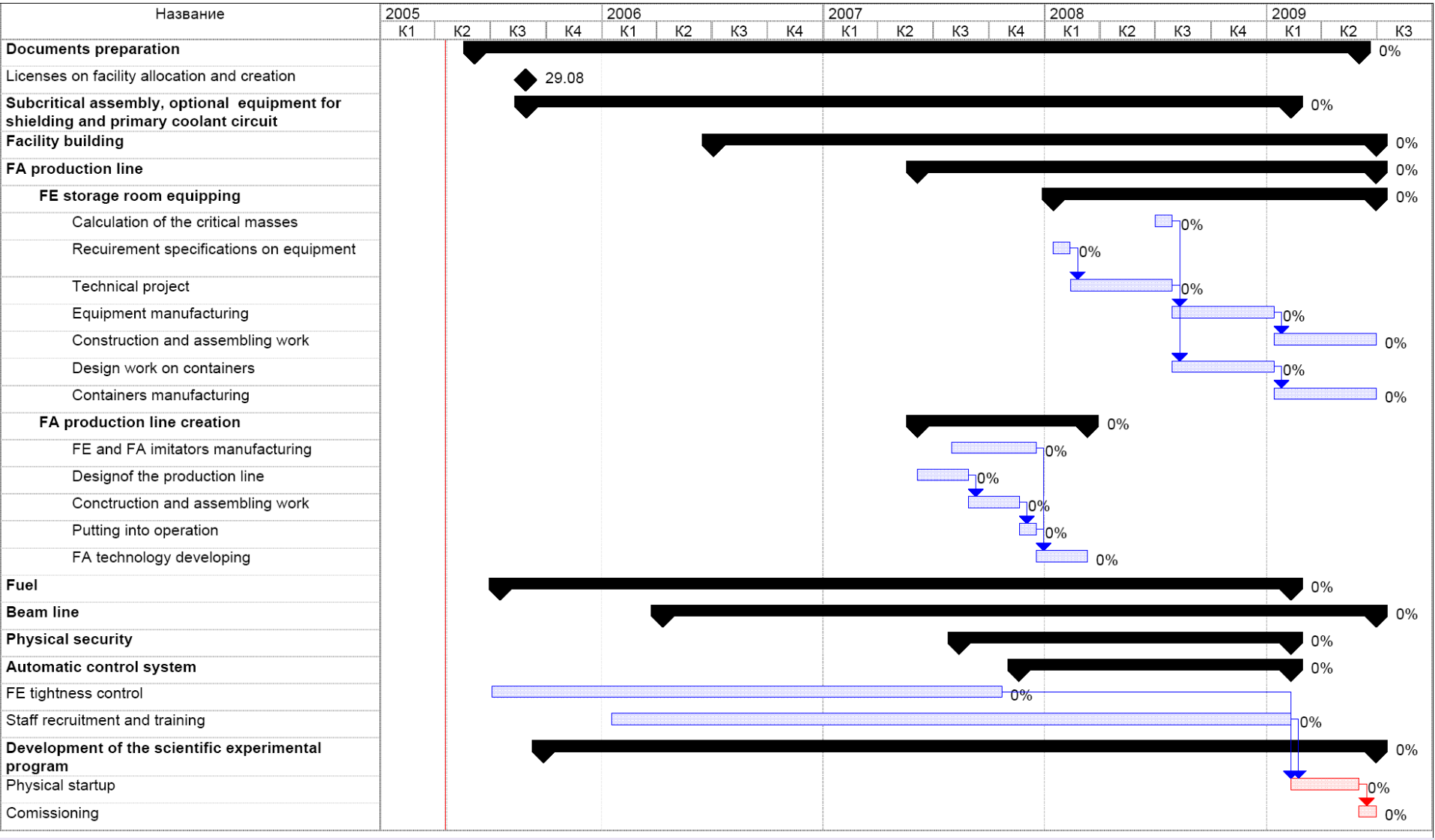
Project Timeline/licensing, blanket/



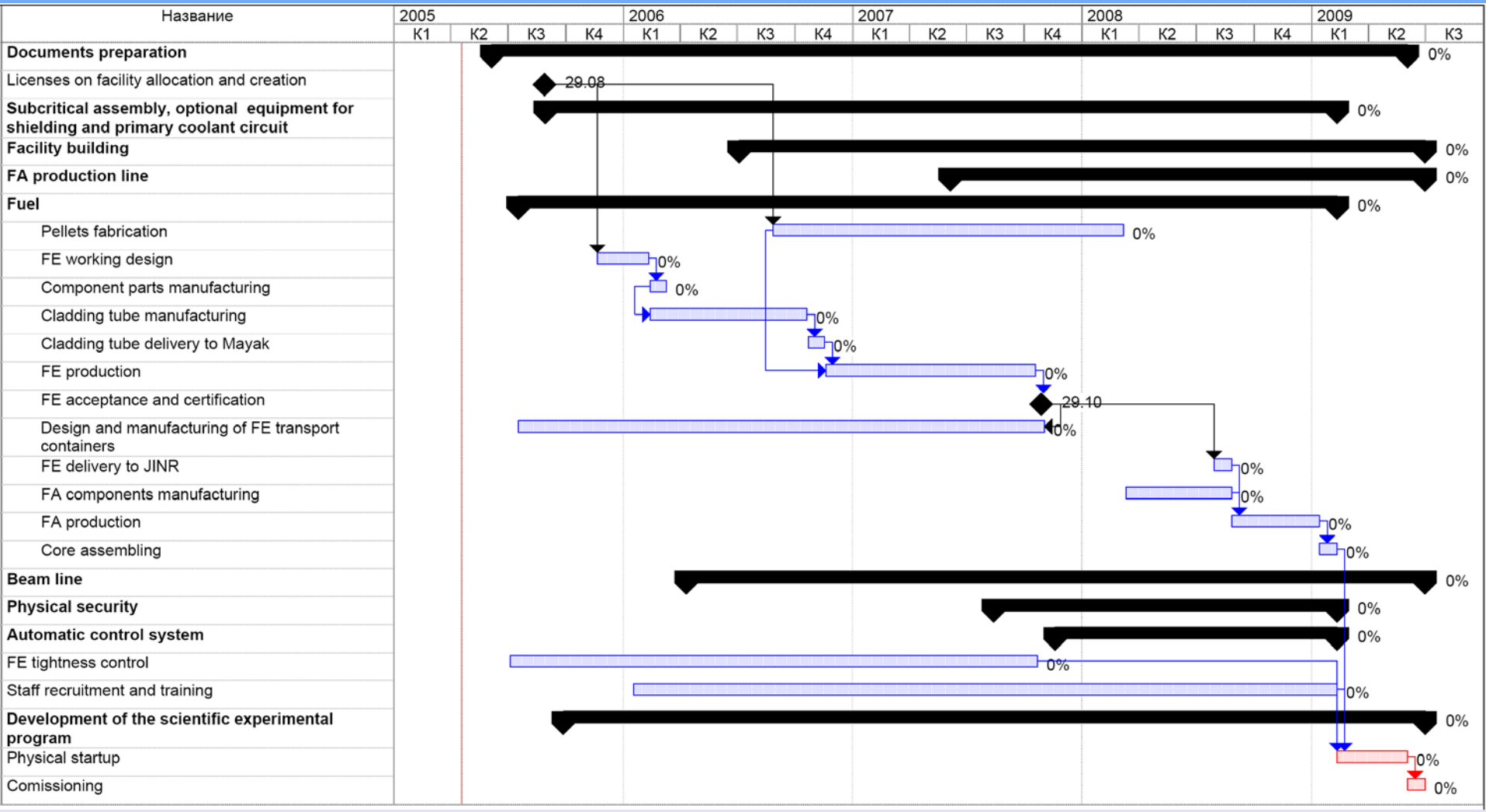
Project Timeline /building/



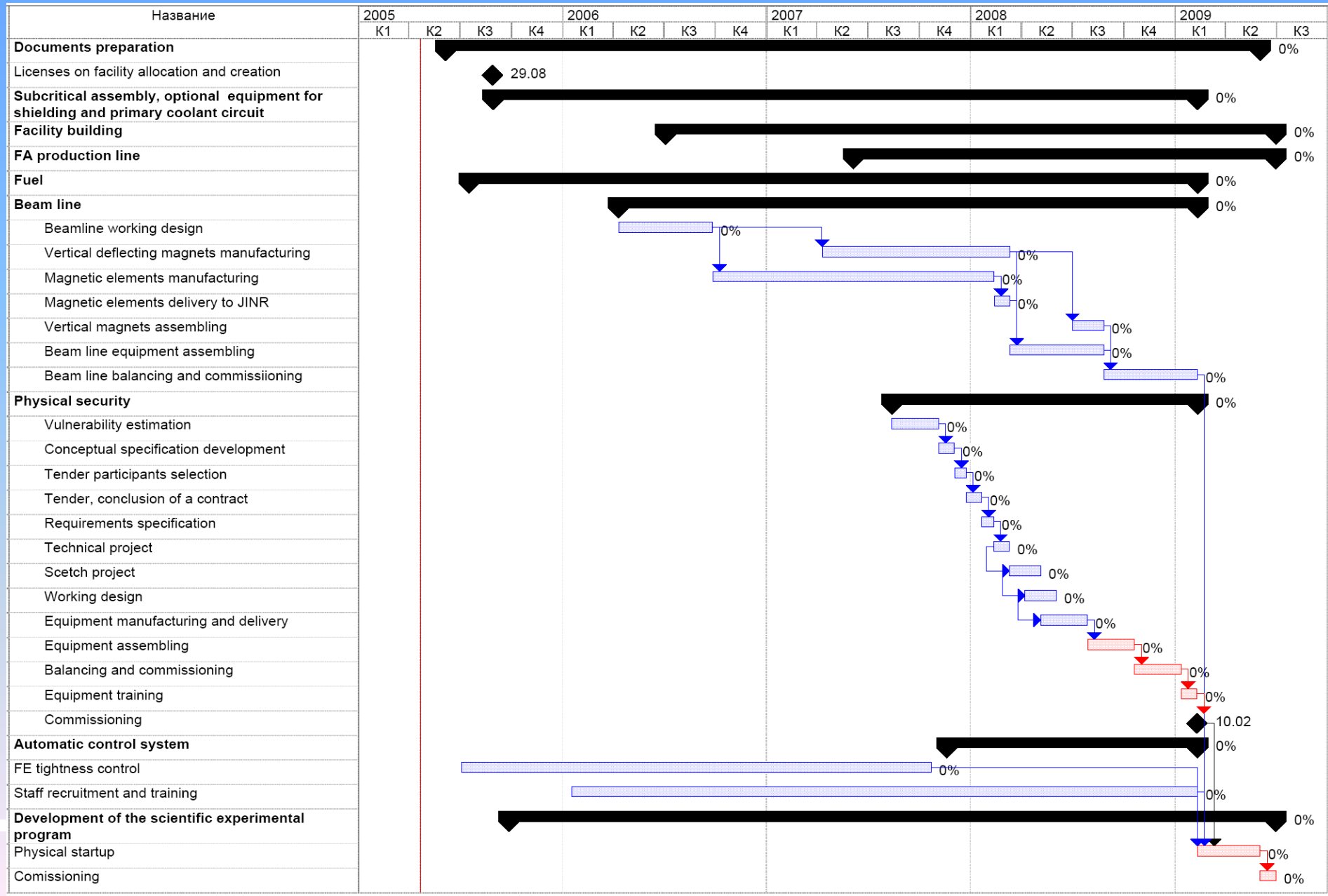
Project Timeline /FA production line/



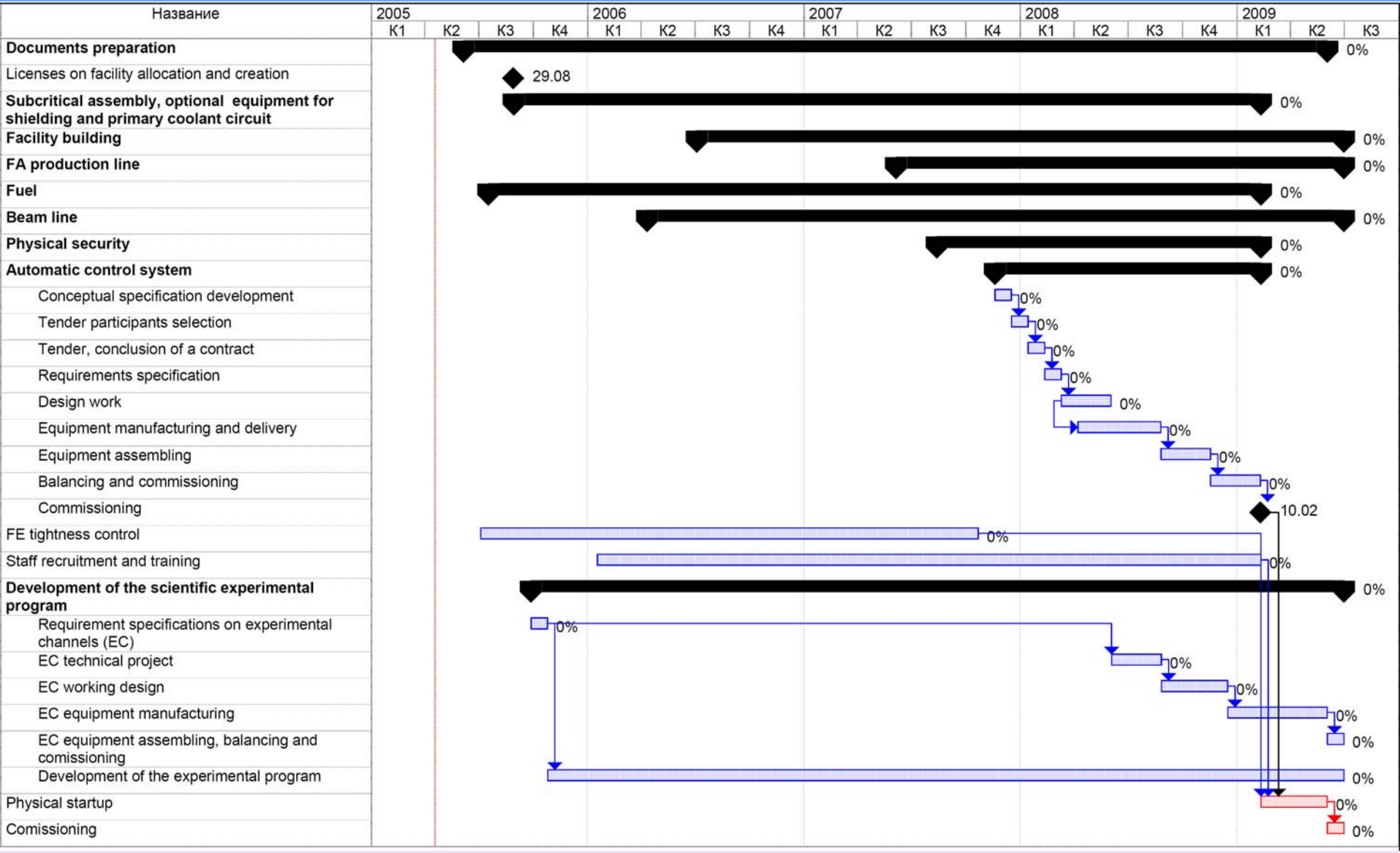
Project Timeline /fuel elements/



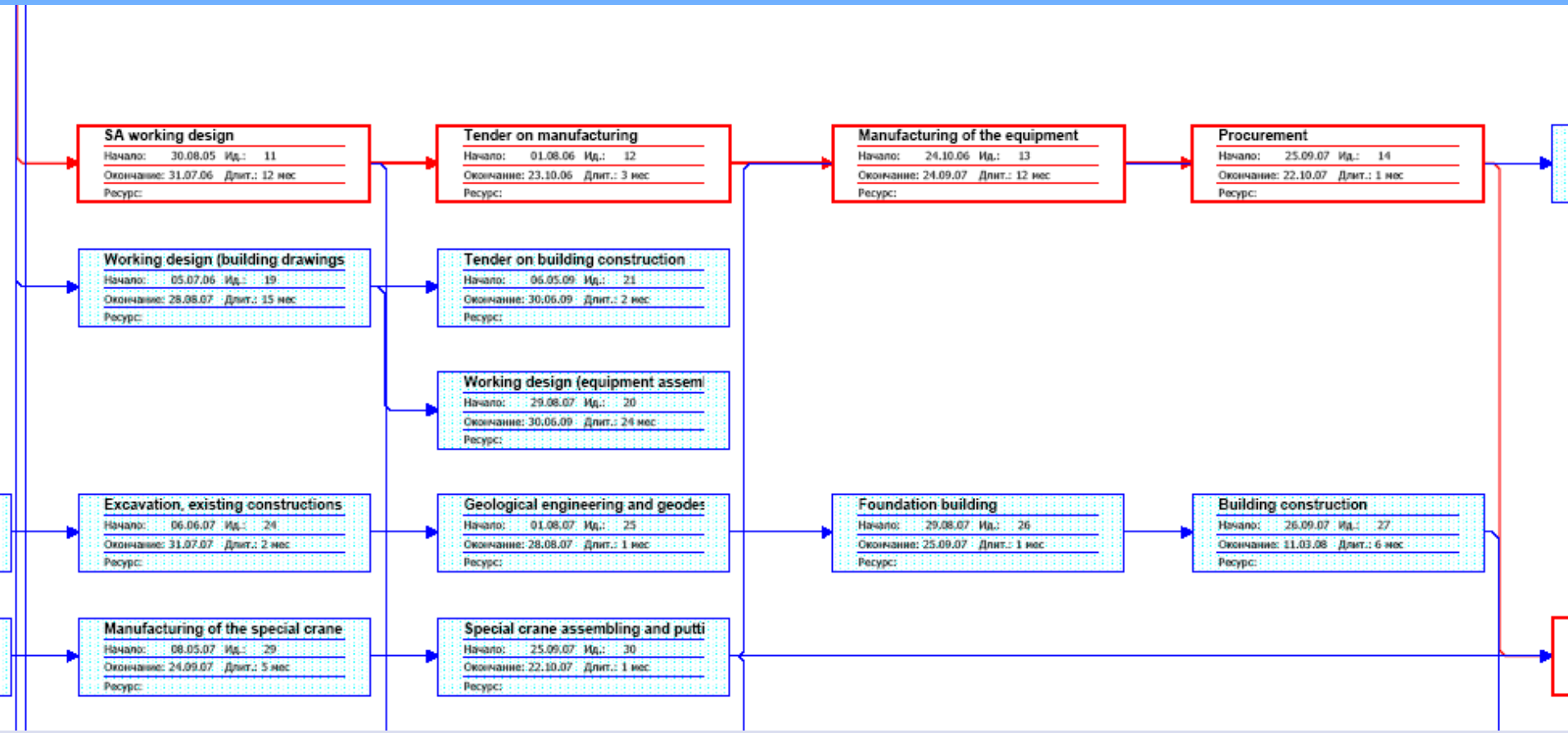
Project Timeline /beam line & phys. sec./



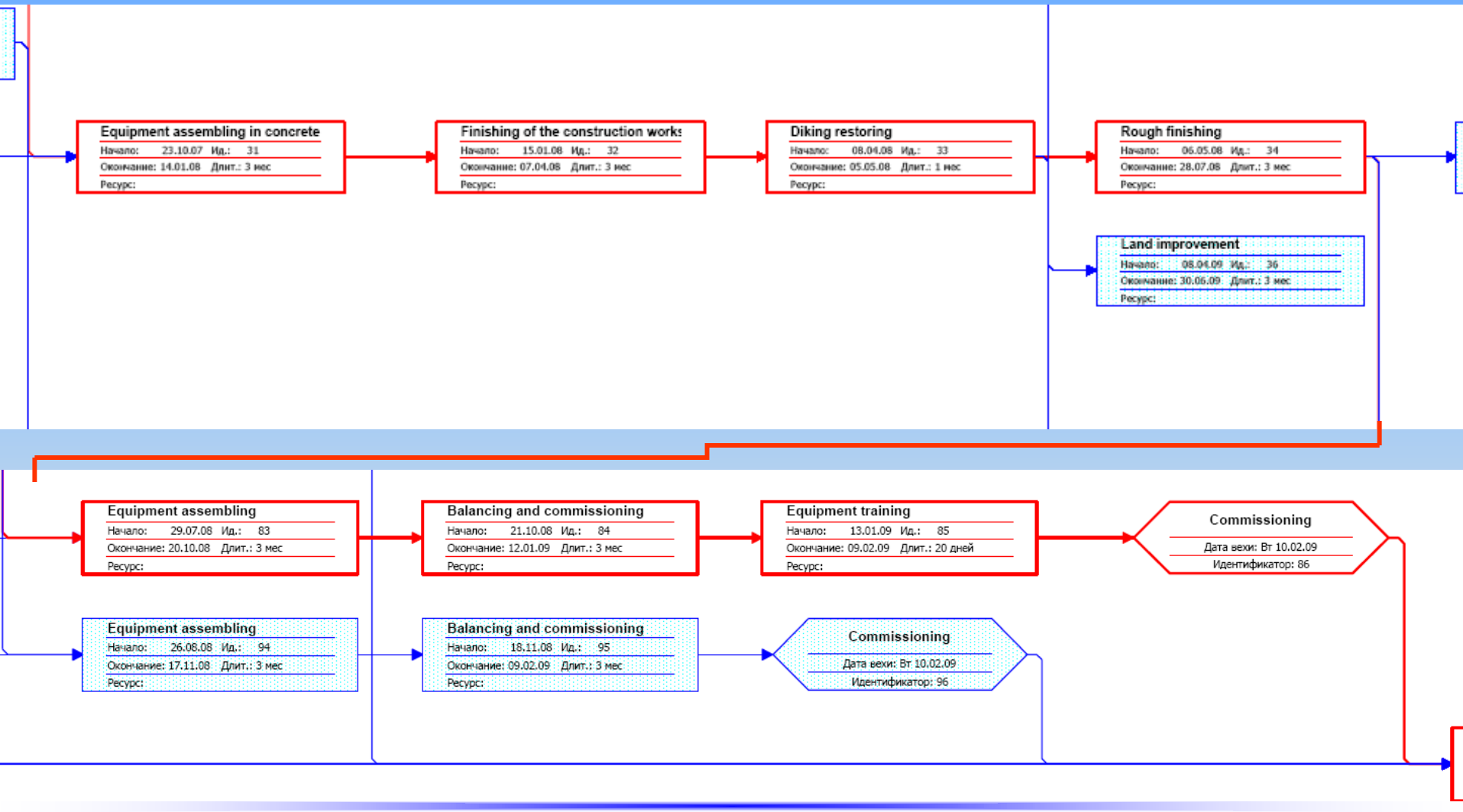
Project Timeline /ACS & exp./



Project Timeline /crit. path: blanket/



Project Timeline /crit. path: building and phys. sec./



Cost assessment