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

Second ECATS meeting

SCK-CEN Headquarters, Brussels, April 20-21, 2005

V. Shvetsov[1], I. Golovnin[2], M. Vorontsov[3], I. Tretyakov[4], B. Ryabov[5]

1- JINR
2 – VNIINM
3- GSPI
4- NIKIET
5- IA "Mayak"

Международная межправительственная организация
International Intergovernmental Organization

Объединенный институт ядерных исследований Joint Institute for Nuclear Research

JINR: INTERNATIONAL SCIENTIFIC CENTRE BRINGING NATIONS TOGETHER

BİRLƏŞMİŞ NŰVƏ TƏDQİQATLARI İNSTITUTU

ՄԻՋՈՒԿԱՅԻՆ ՅԻՋԻԿԱՅԻ ՄԻԱՑՅԱԼ ԻՆՍՏԻՏՈՒՏ

АБ'ЯДНАНЫ ІНСТЫТУТ ЯДЗЕРНЫХ ДАСЛЕДАВАННЯЎ

ОБИДЕНЕН ИНСТИТУТ ЗА ЯДРЕНИ ИЗСДЕДОВАНИЯ

VIỆN LIÊN HIỆP NGHIEN CỨÚ HẠT NHÀN

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БІРІККЕН ЯДРОЛЫҚ ЗЕРТТЕУ ИНСТИТУТЫ

통합 핵 지 쉐 연 구 소

INSTITUTO UNIFICADO DE INVESTIGACIONES NUCLEARES

INSTITUTUL UNIFICAT DE CERCETARI NUCLEARE

ЦӨМИЙН ШИНЖИЛГЭЭНИЙ НЭГДСЭН ИНСТИТУТ

ZJEDNOCZONY INSTYTUT BADAŃ JĄDROWYCH

ОБЪЕДИНЕННЫЙ ИНСТИТУТ ЯДЕРНЫХ ИССЛЕДОВАНИЙ

INSTITUTUL UNIFICAT DE CERCETARI NUCLEARE

SPOJENÝ ÚSTAV JADROVÝCH VÝSKUMOV

ЯДРОВИЙ ТАДҚИҚОТЛАР БИРЛАШГАН ИНСТИТУТИ

ОБ'ЄДНАНИЙ ІНСТИТУТ ЯДЕРНИХ ДОСЛИДЖЕНЬ

SPOJENÝ ÚSTAV JADERNÝCH VÝZKUMŮ

Co-operation with Germany

- **JINR's partners are**
  - **67 institutions located in 45 cities**
- **Research activities are regulated by the Agreement between BMBF and JINR concluded in 1991**

• Location of centres collaborating with JINR

JINR Dubna

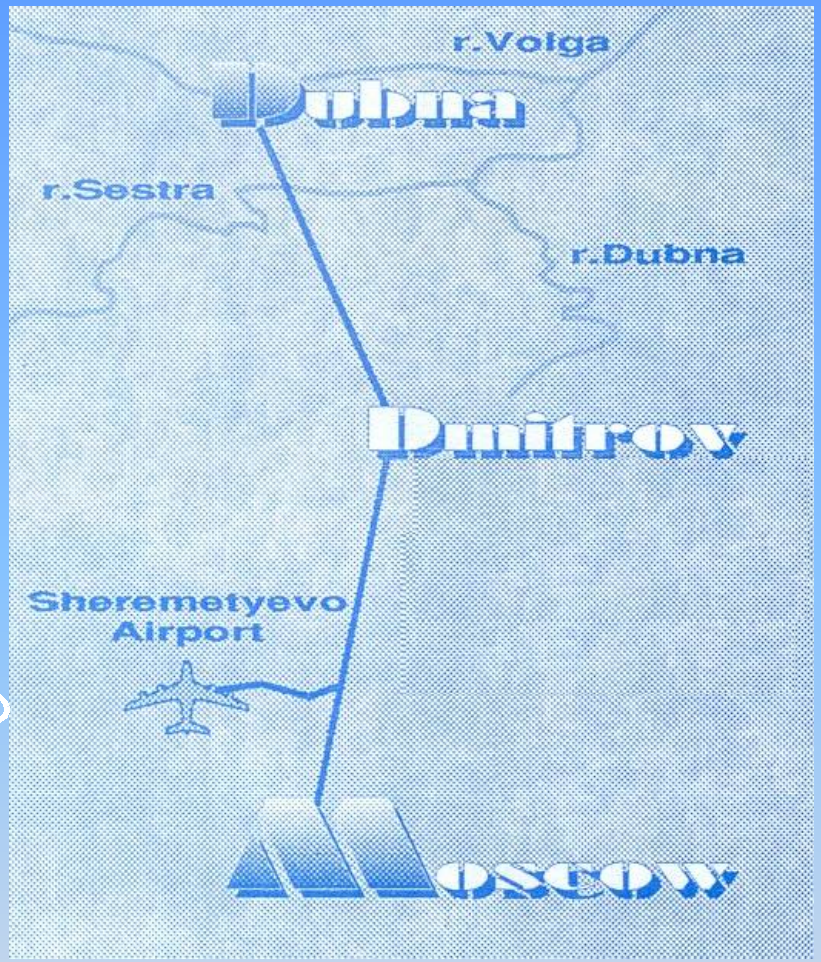


Photo of Dubna from satellite
(look from 250 km height)

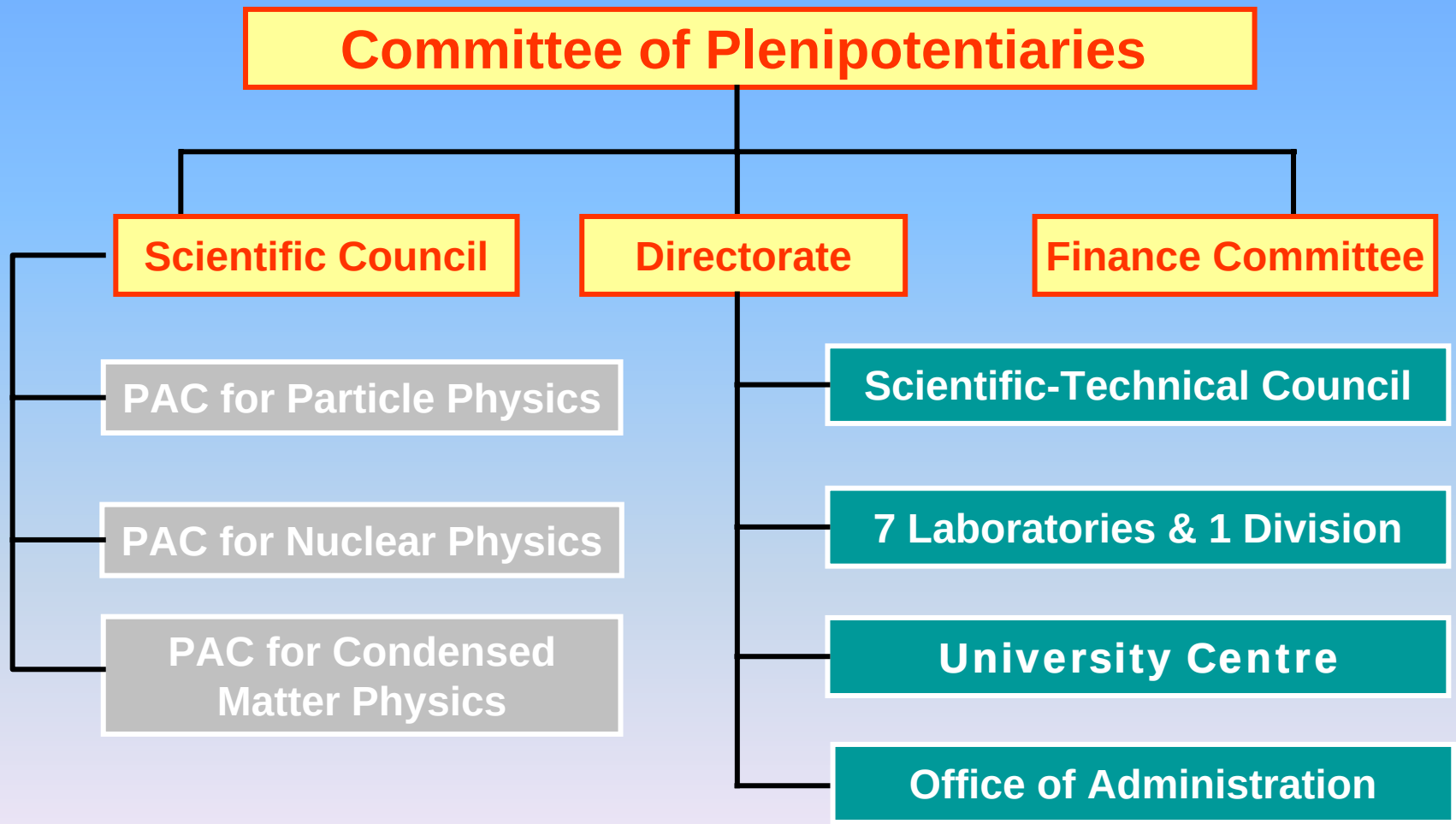
Joint Institute for Nuclear Research (JINR) is an international intergovernmental organization located in Dubna, Russian Federation, about 120 km north of Moscow

JINR Dubna

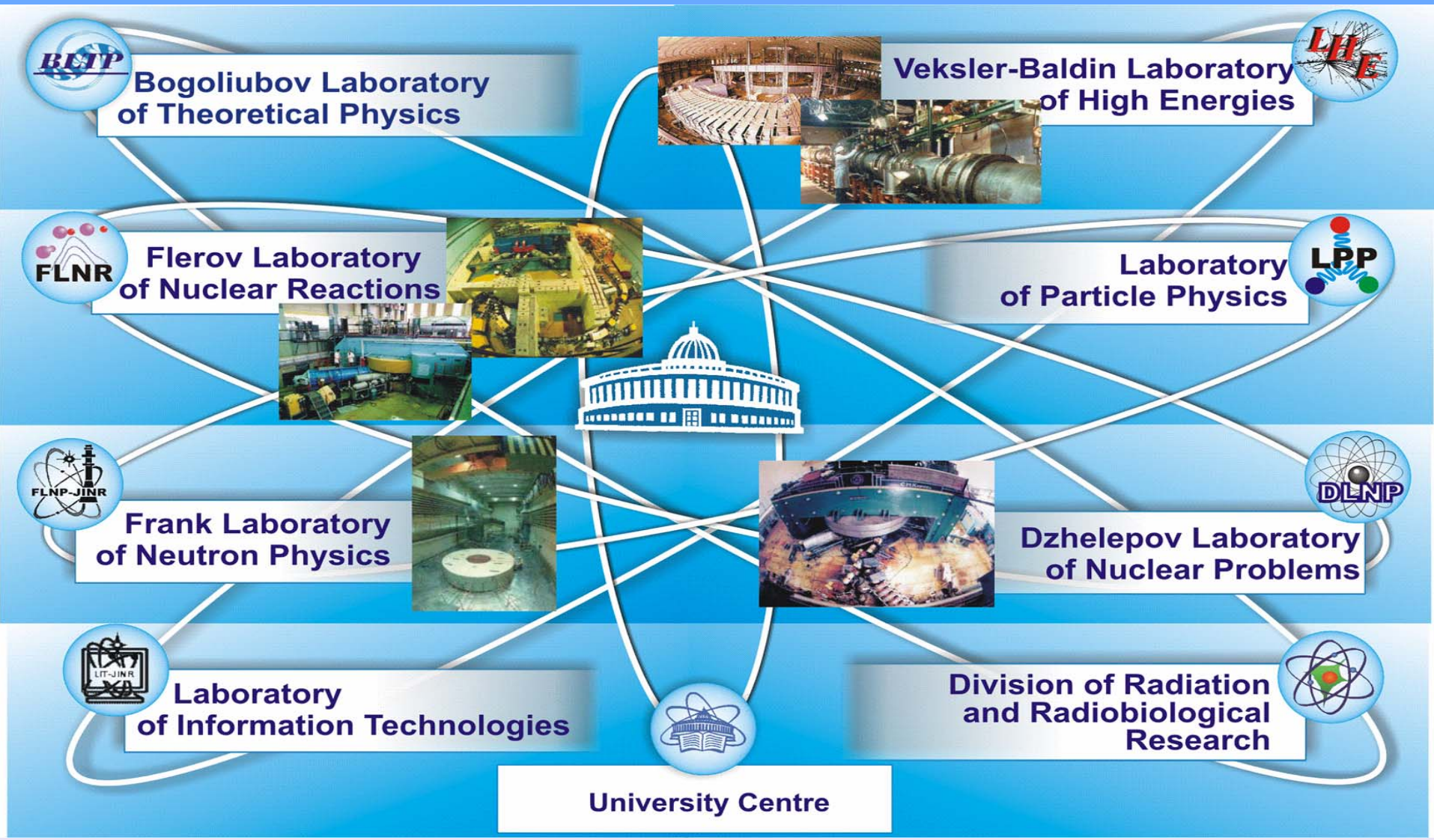
Basic Documents

26.03.1956:	Foundation of JINR
23.09.1956:	Adoption of the JINR Charter
1.02.1957:	JINR was registred by UN
23.06.1992:	Renewed Charter signed
24.09.1997:	UNESCO – JINR Agreement
2.01.2000:	The Federal Law on the Russian Government – JINR Agreement

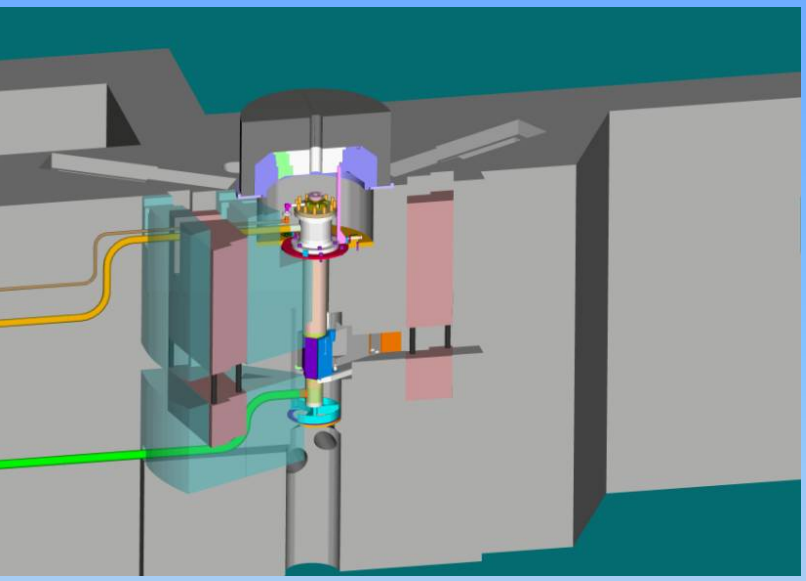
Governing Bodies & Structure



JINR Labs and Facilities



Plan for Creation and Operation of IREN source



Metallic Pu core, k_{eff} = 0.97

Power 12 kWt

Electron beam energy – 200 MeV

Beam power -10 kWt

Neutron flux – 10^{15} n/s

Neutron pulse duration – 400 ns

Repetition rate – 150 Hz

2004	2005	2006	2007	2008-2009
Creation and start, first stage				
			Full completion	
	Modernization of spectrometers			
				Data taking

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)

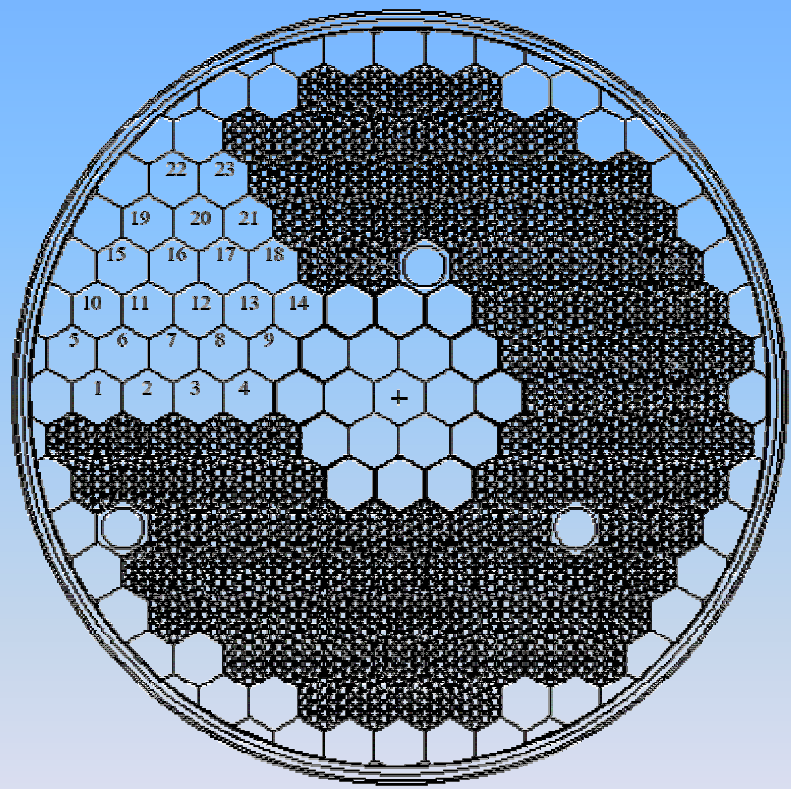
- Forschungszentrum Karlsruhe - FZK, Institut für Reaktorsicherheit, Dr. Cornelis Broeders;
- Kungliga Tekniska Högskolan - KTH, Nuclear and Reactor Physics, Dr. Waclaw Gudowski;
- Centro de Investigaciones Energéticas Medioambientales y Technologies - CIEMAT , Dr. Enrique Miguel Gonzalez Romero;
- Commissariat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

Basic Data

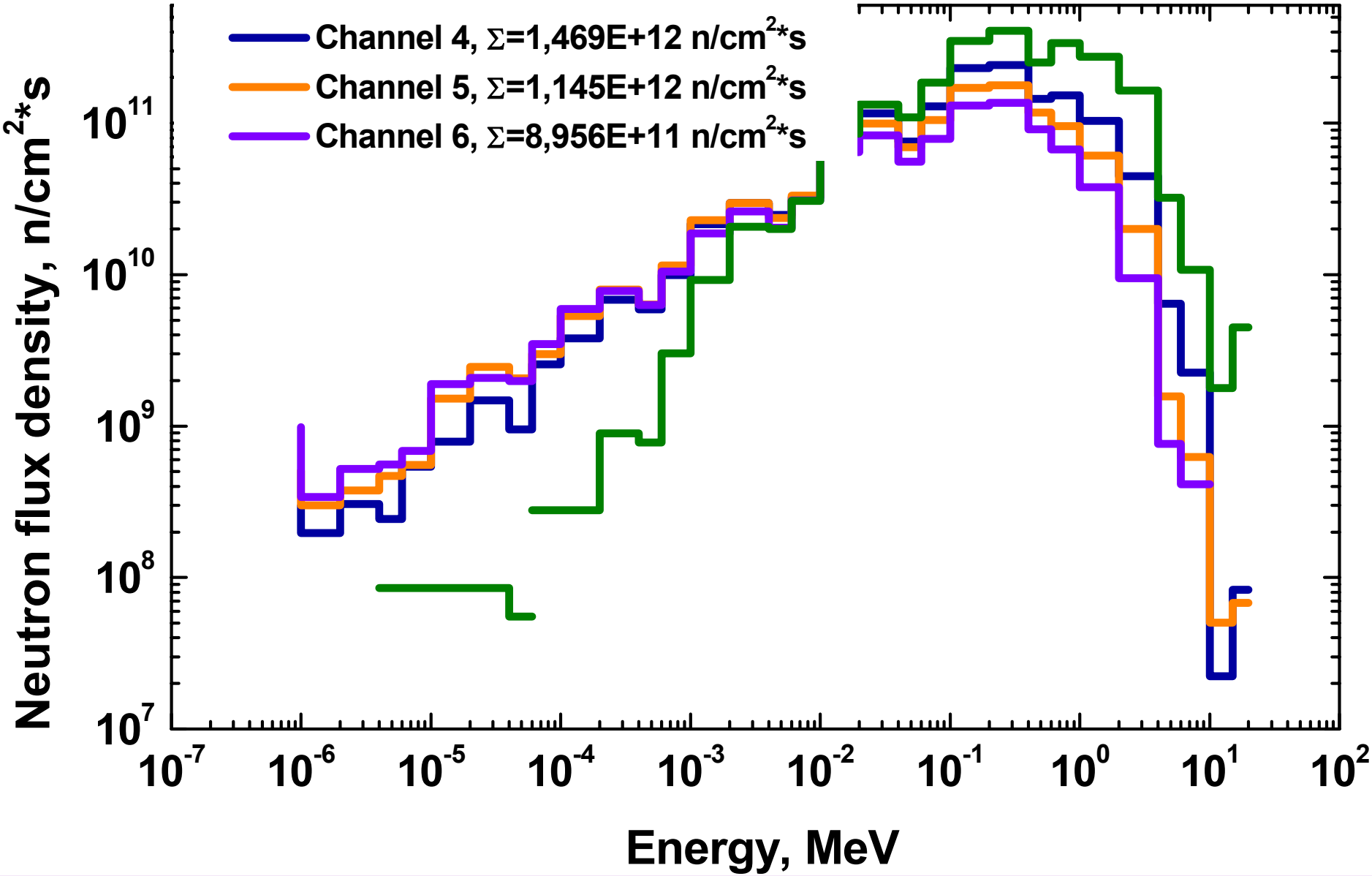
k_{eff}	~0,95
Fuel loading	< 420 kg
Fission power	27,6 kW
Cooling	air
Core	
Coolant flow rate, G	~ 0,6 kg/s
velocity, v	10 m/s
Presure, P *(inlet)*	0,12-0,135 MPa
Temperature, T *(inlet, outlet)*	50/96 ºC
Target (Pb)	
Coolant flow rate, G	~ 0,0067 kg/s
Velocity, v	50 m/s
Pressure, P *(inlet)*	0,12-0,135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



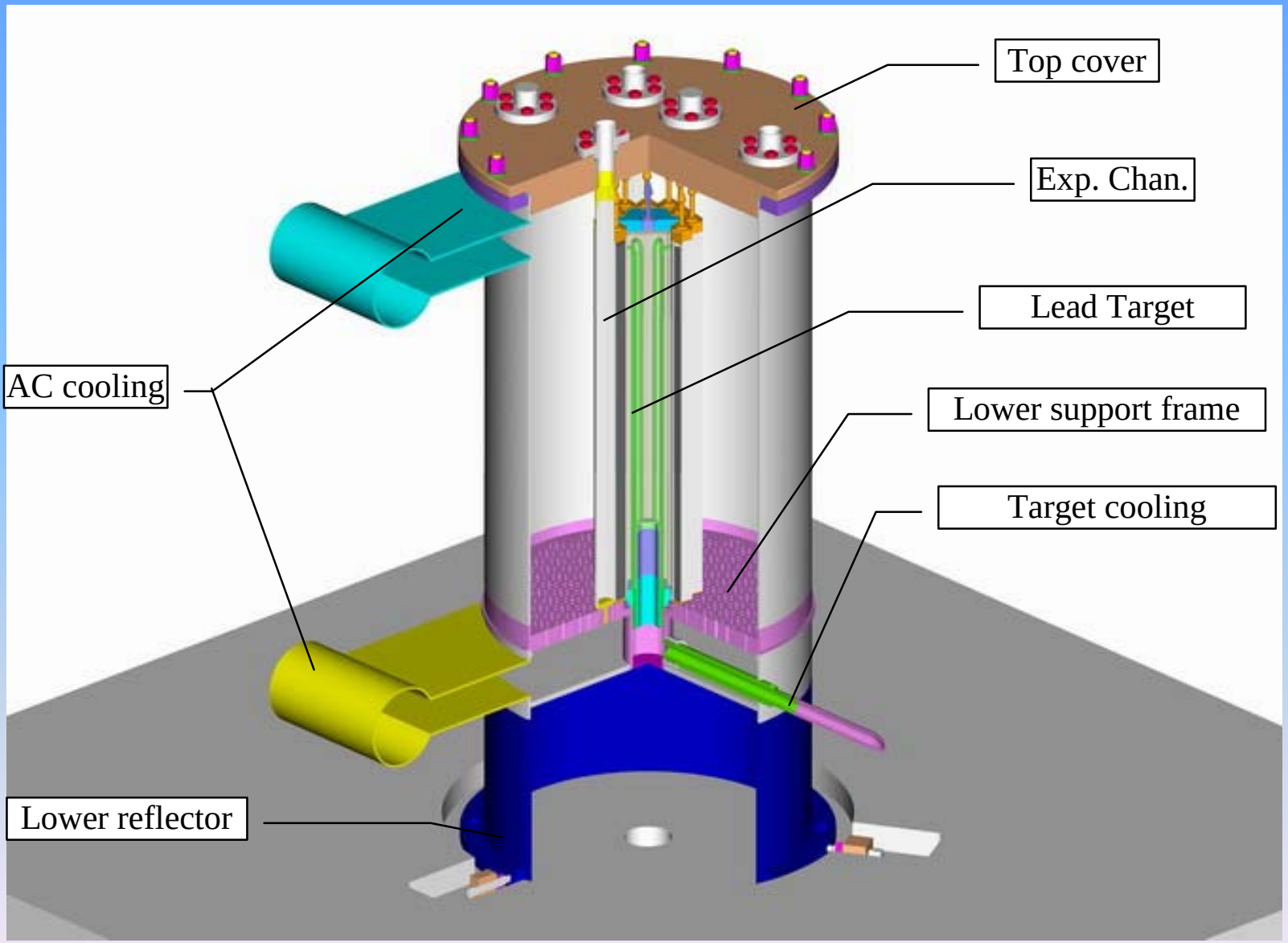
Subcritical Blanket/calculations



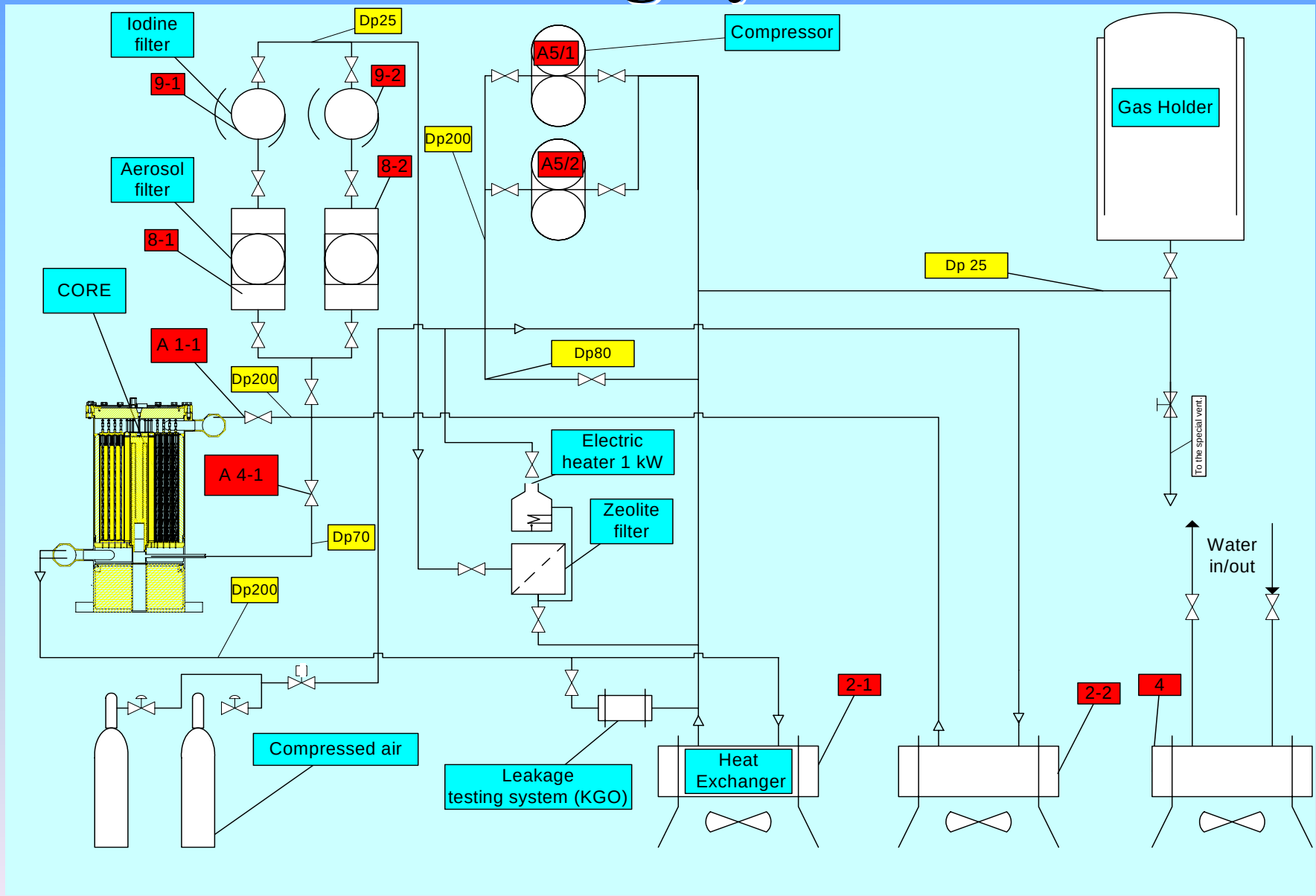
Subcritical Blanket/ neutronics

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/($cm^2 \cdot s$)**
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/($cm^2 \cdot s$)
Max fluence of fast neutrons	$8.0 \cdot 10^{19}$ 1/cm^2

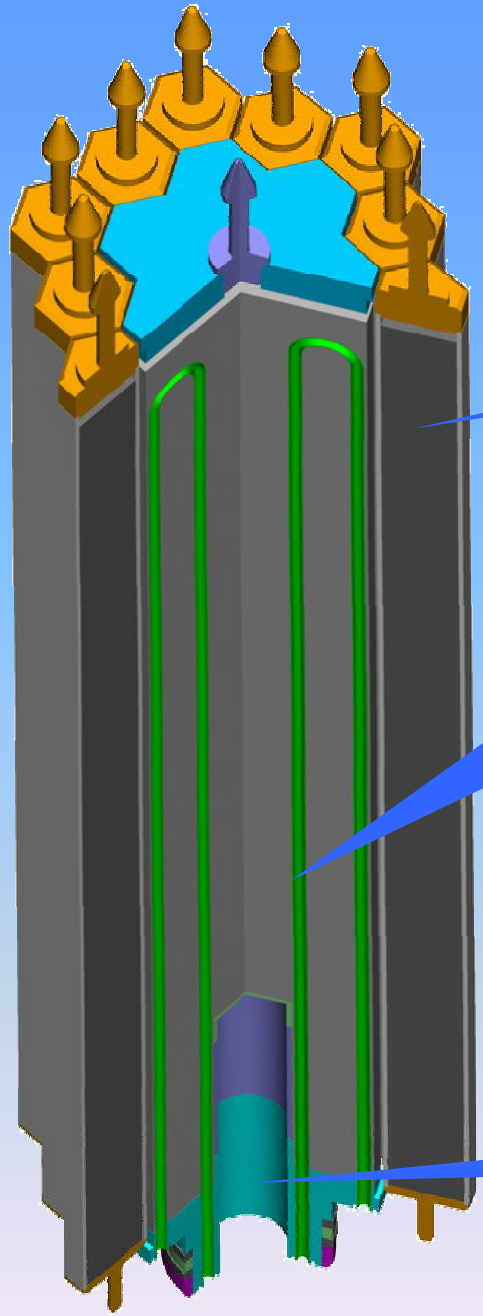
Subcritical Blanket/design



Cooling System



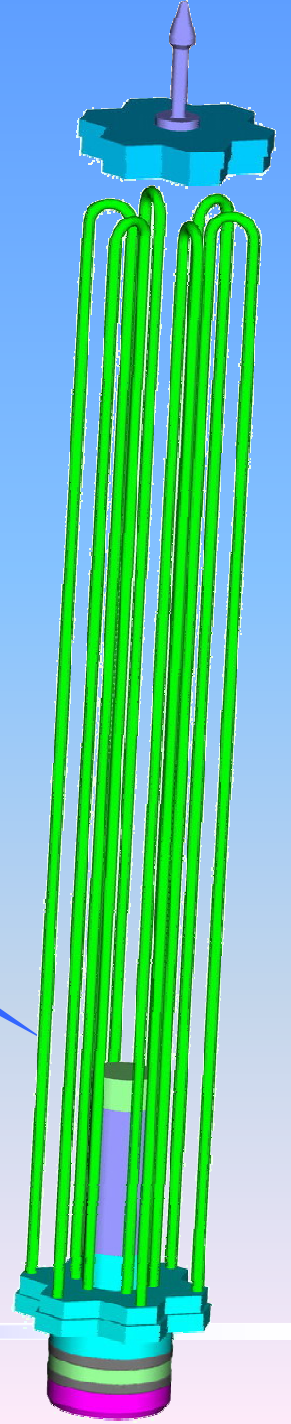
Target/design



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

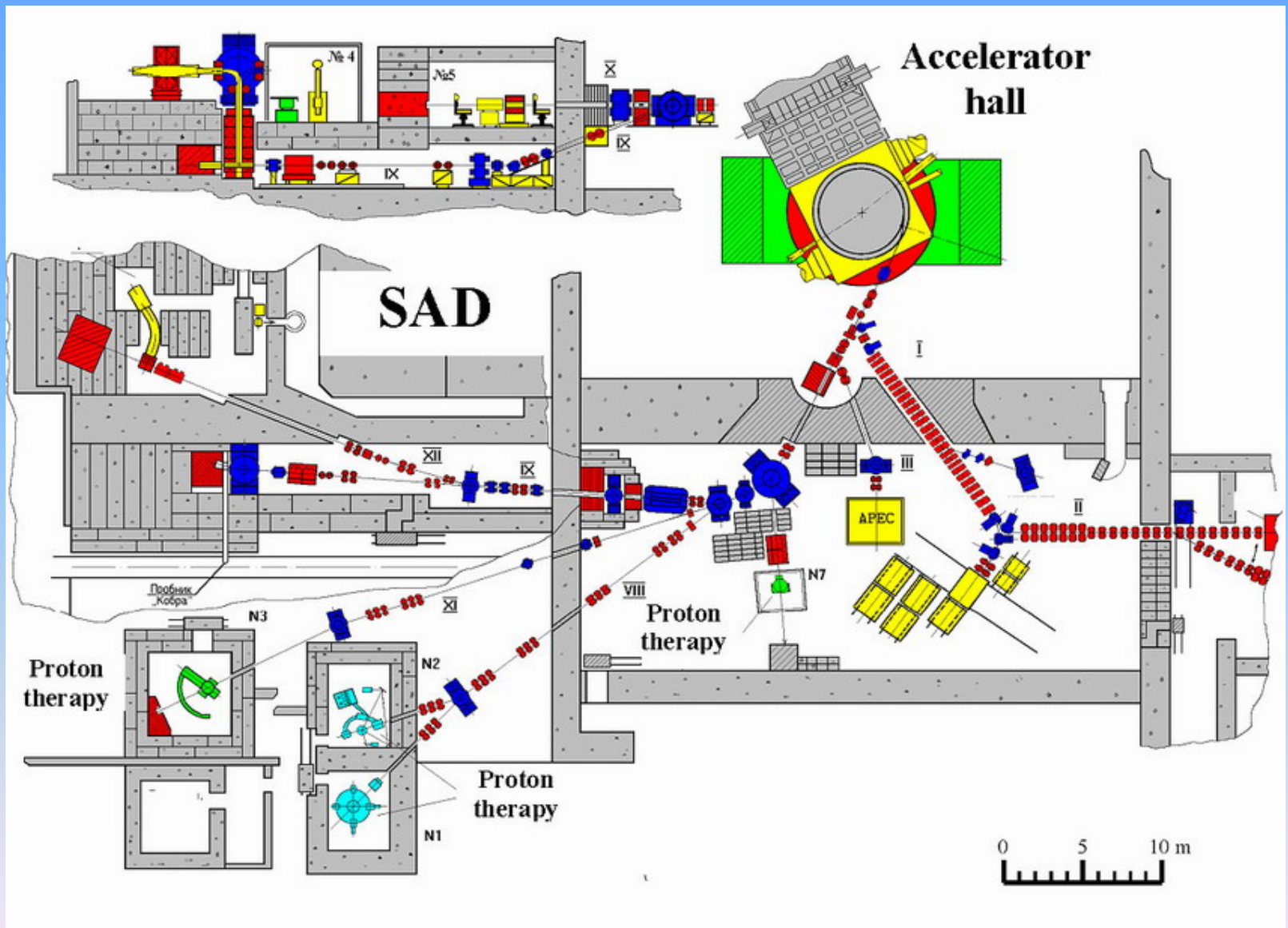
Beam Characteristics	
RF structure (RF frequency, phase width)	14.4MHz, 50degree
Macro pulse structure (filling of RF pulses)	
Long duration Beam Pulse characteristics (duty cycle, …)	0.5%duty
Final beam energy	659MeV
Beam energy spread and stability	3.1MeV
Final beam intensity (average, peak)	3.2 mkA 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)

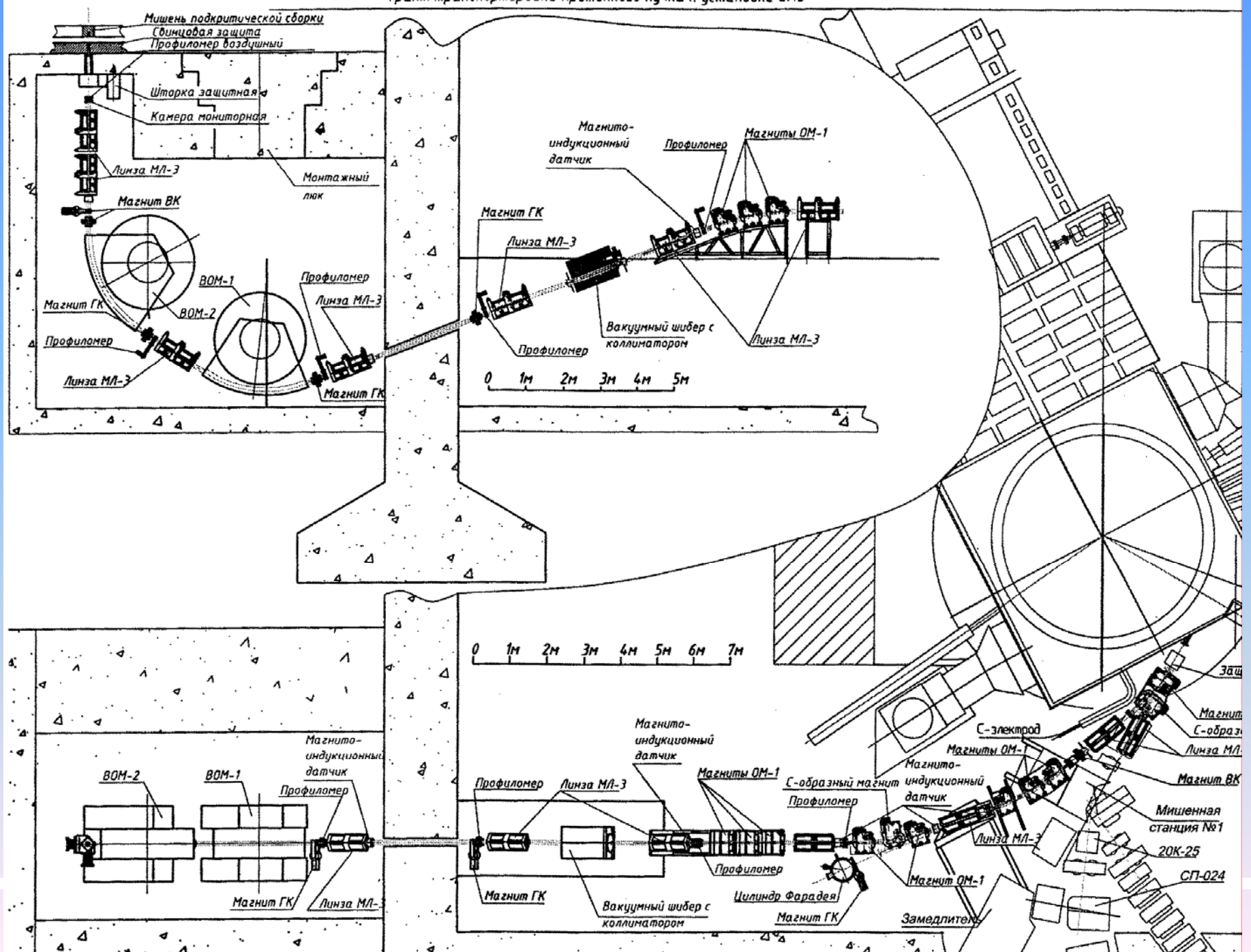
Possibility to shorten the pulse width down to 1 mks is under investigation

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
Магнит ГК
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
ВОМ-2
ВОМ-1
Магнито-индукционный датчик
Профиломер
Магнит ГК
Линза МЛ-
Профиломер
Линза МЛ-3
Магнито-индукционный датчик
Магниты ОМ-1
Профиломер
Магнит ГК
Вакуумный шибер с коллиматором
Цилиндр Фарадея
Магнит ГК
С-образный магнит
Профиломер
Магнито-индукционный датчик
Магнит ОМ-1
Замедлитель
С-электрод
Магниты ОМ-
Линза МЛ-3
Мишенная станция №1
20К-25
СП-024

Initial data for SAD FE design

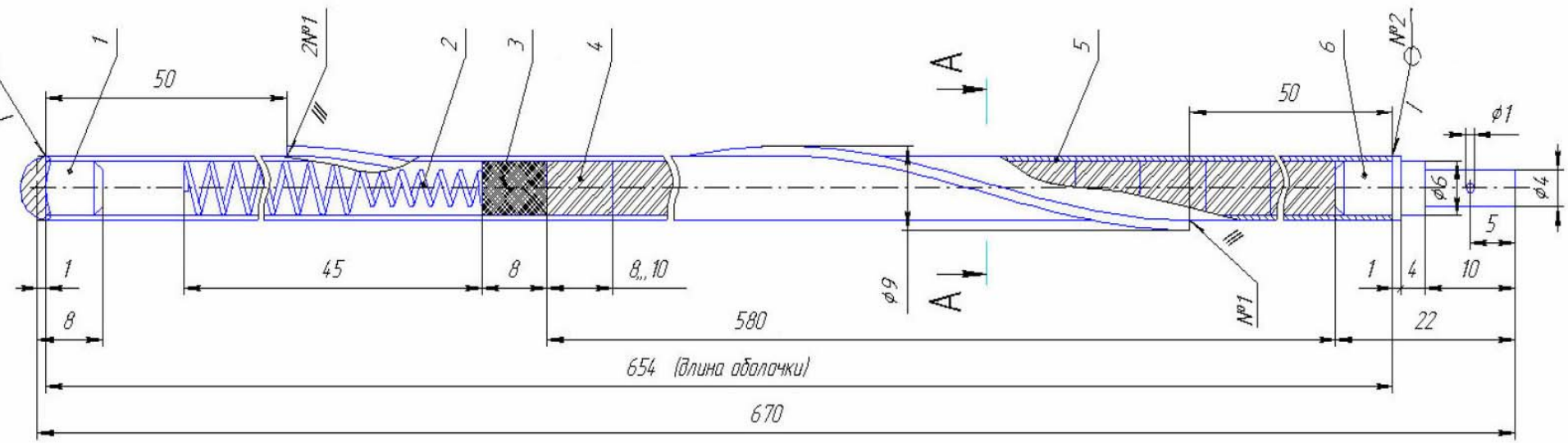
Operating Conditions

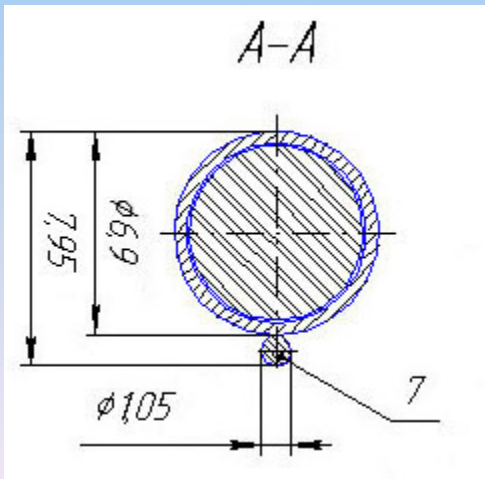
- Maximum Dose for Constructional Materials of Fuel Element – 0.25 dpa.
- Fuel Maximum Burn up – 0.1 % h.a.
- Maximum Linear Power of Fuel Element – 0.275 kW/sm.
- Maximum Temperature of Fuel Element Cladding - 150°C.
- Core Coolant - Dry, Dust-free Air.
- Maximum Coolant Temperature at Core Output - 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.

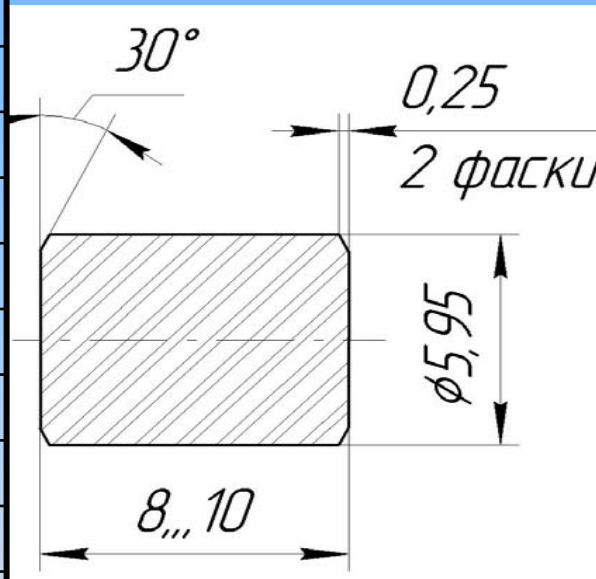
FE design


1
50
2№1
2
3
4
A
5
6
№2
50
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

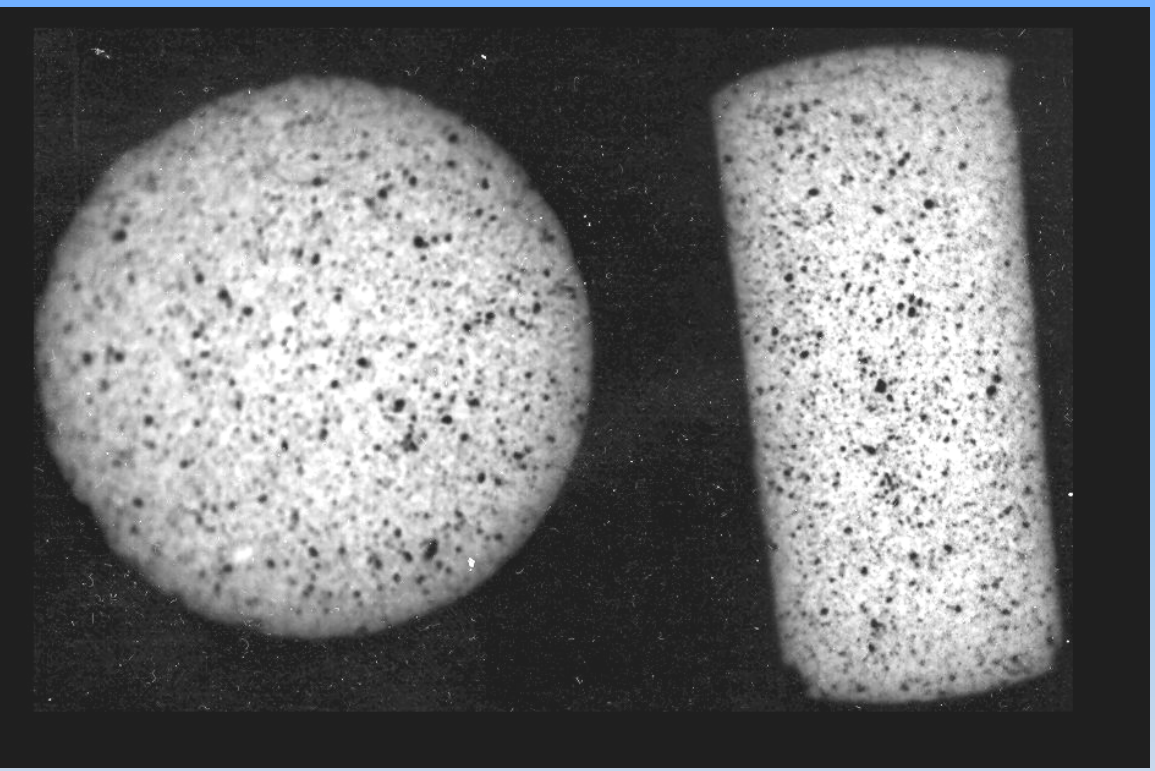
Fuel pellet

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



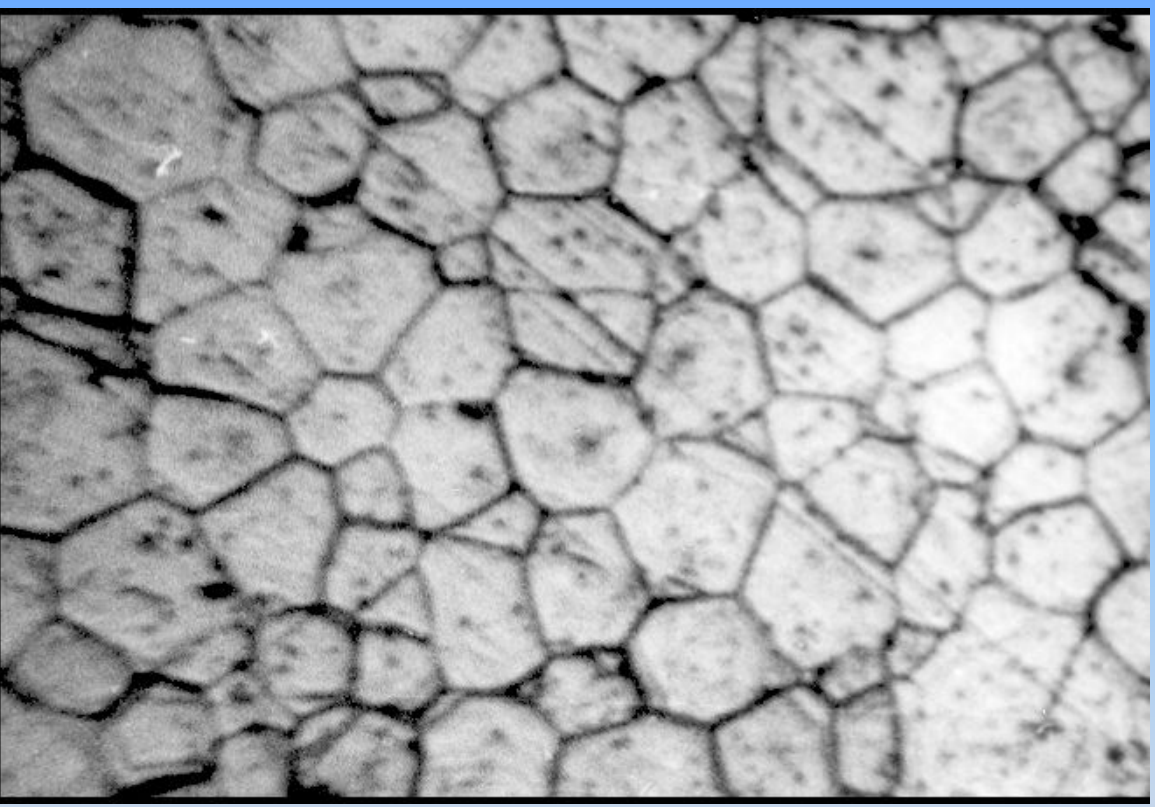
α-radiography

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

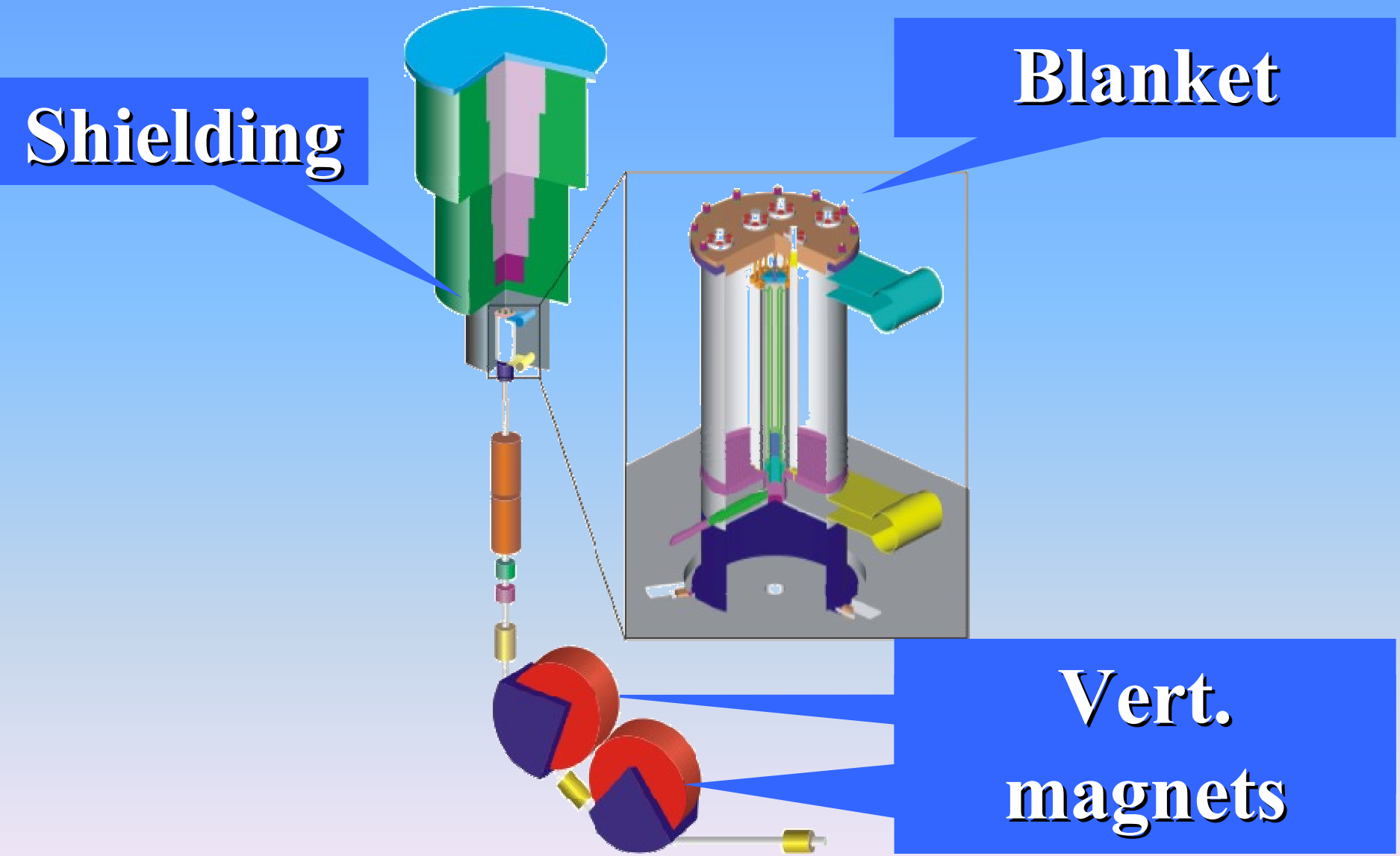


Microscopy study of the microsections processed in HNO_3 and HF acids

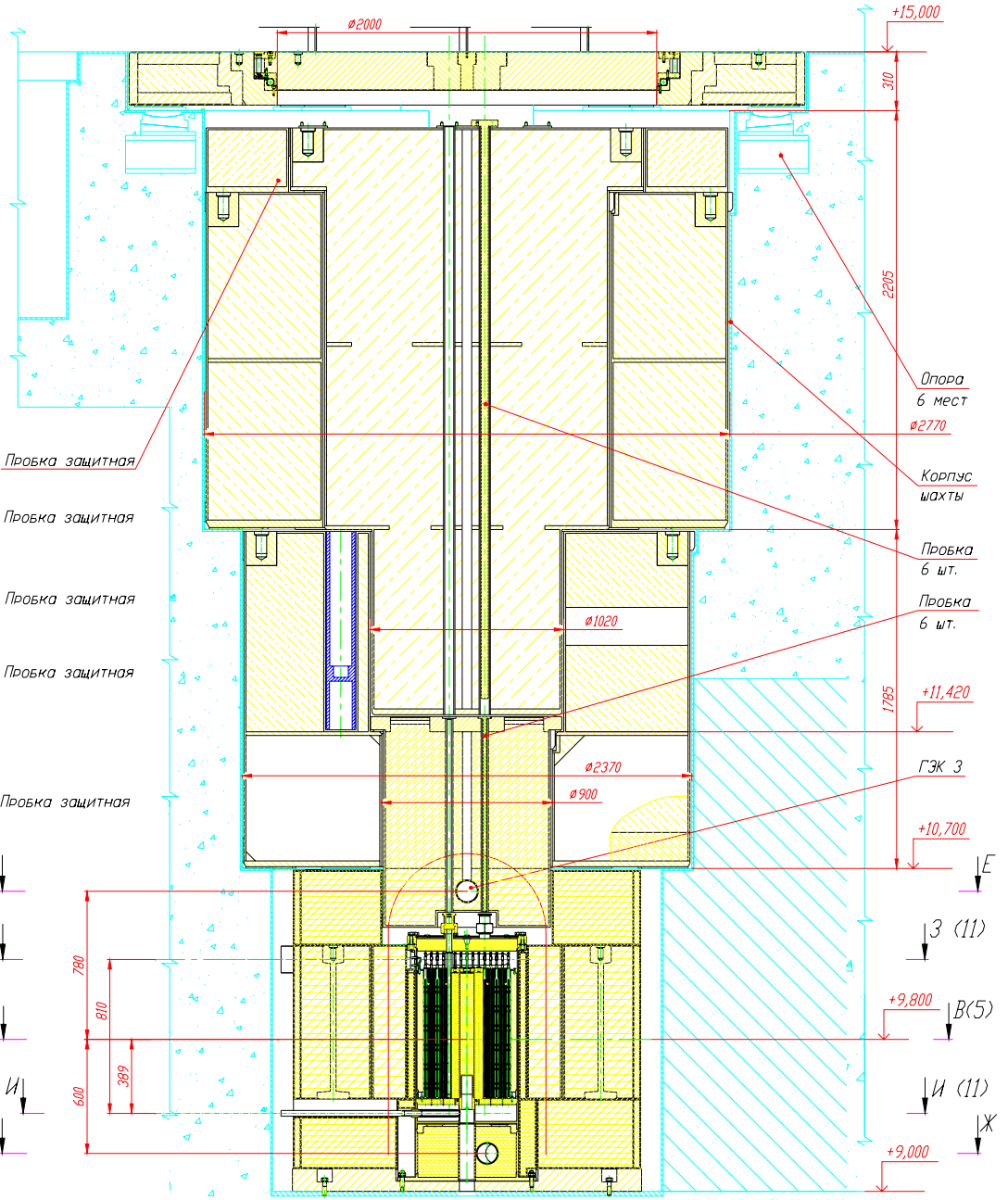
Pores diameter < 100 mkm and area less than 10% of microsection area

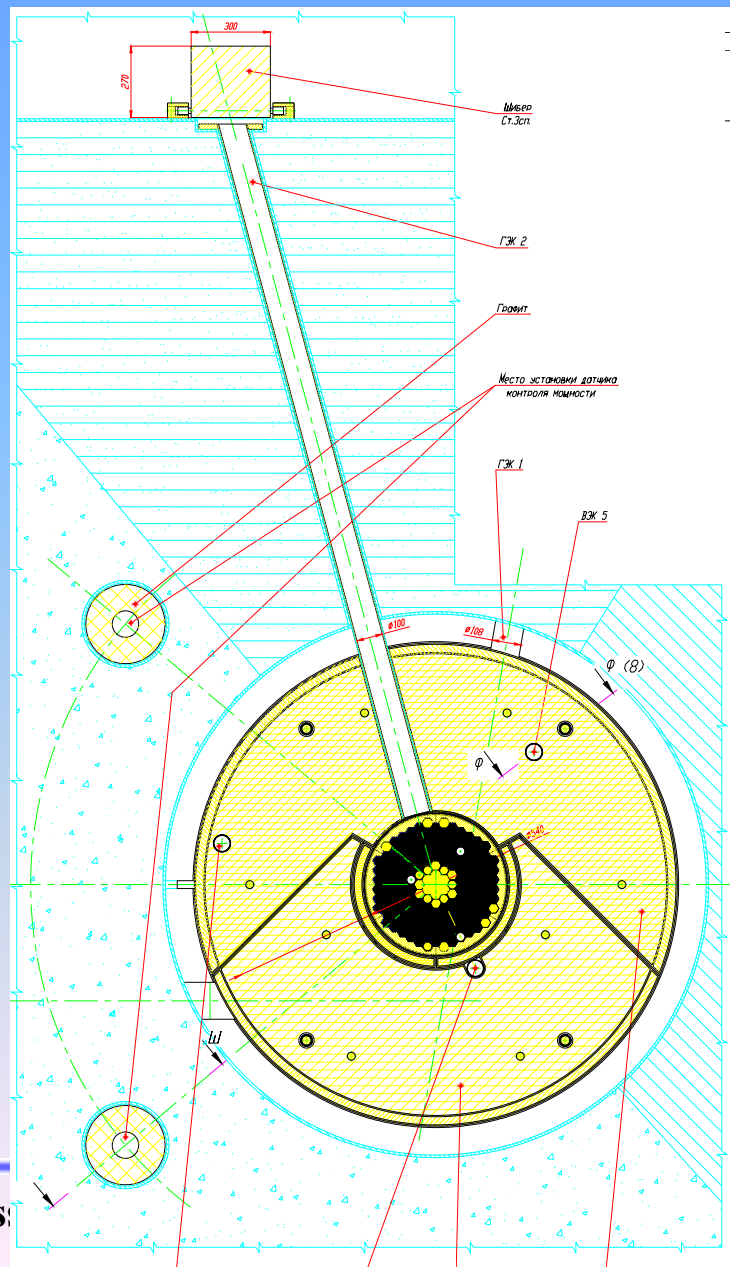
Grain diameter should be < 50 mkm (20-25 for that sample)

General Layout



General Layout

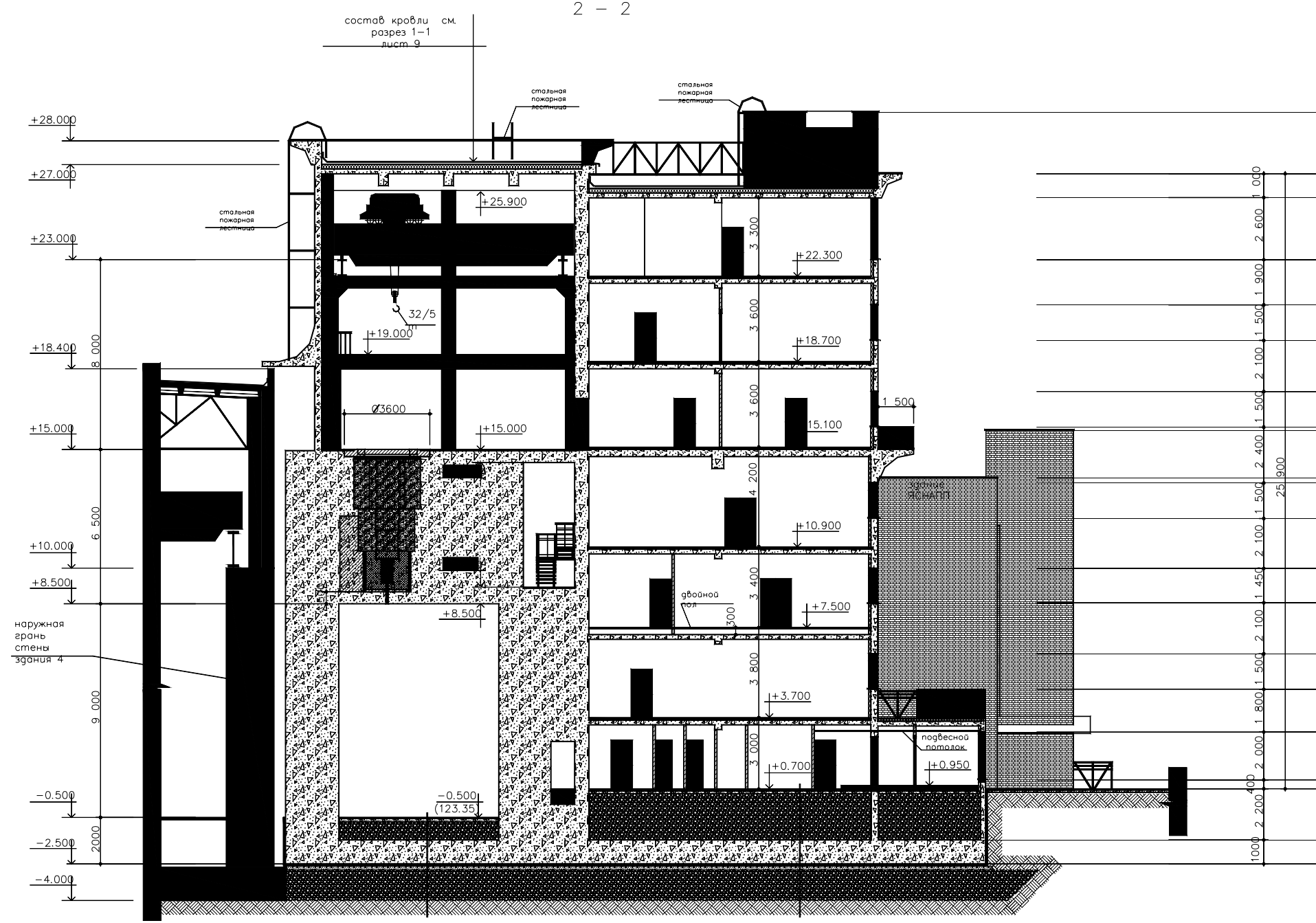


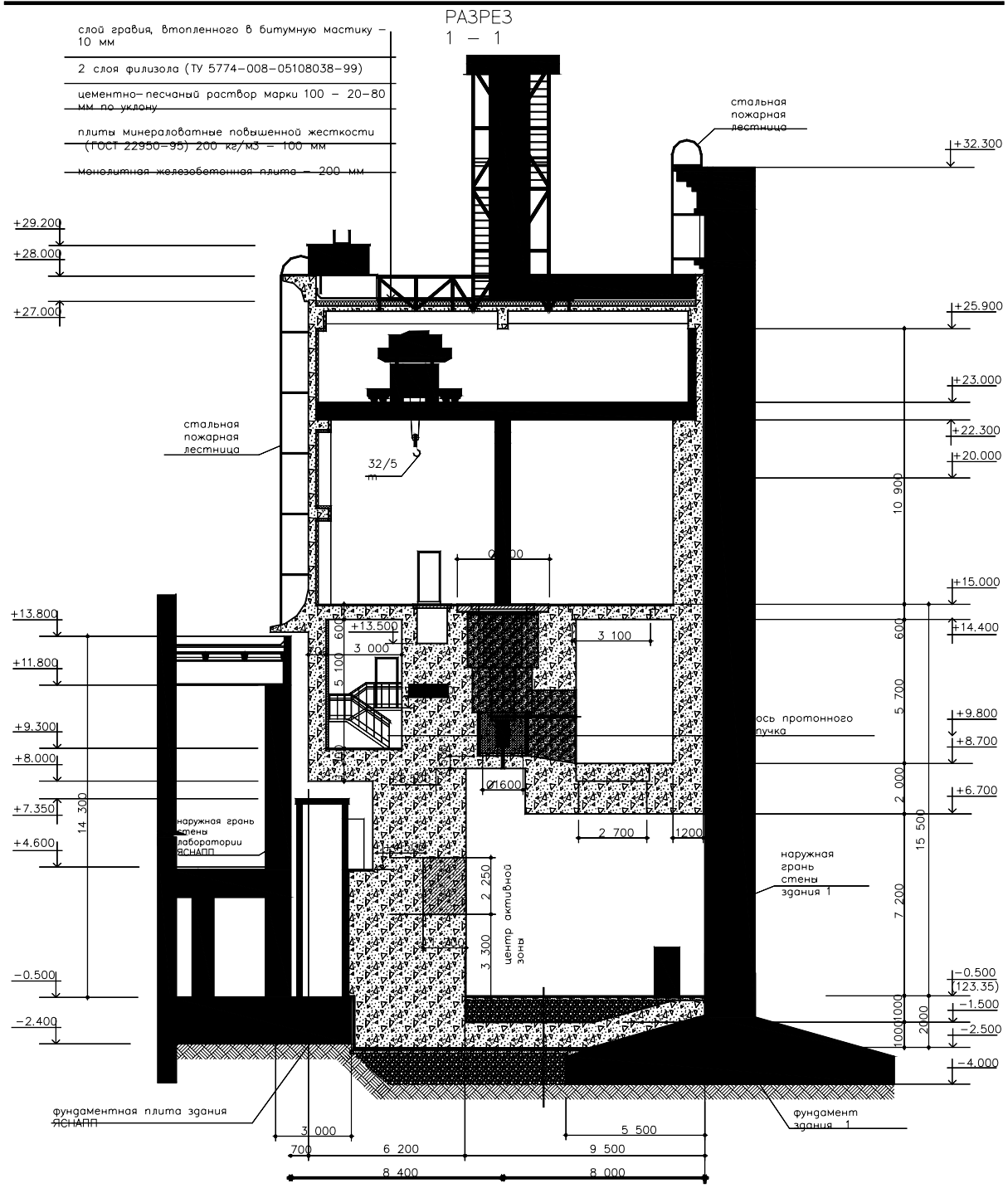


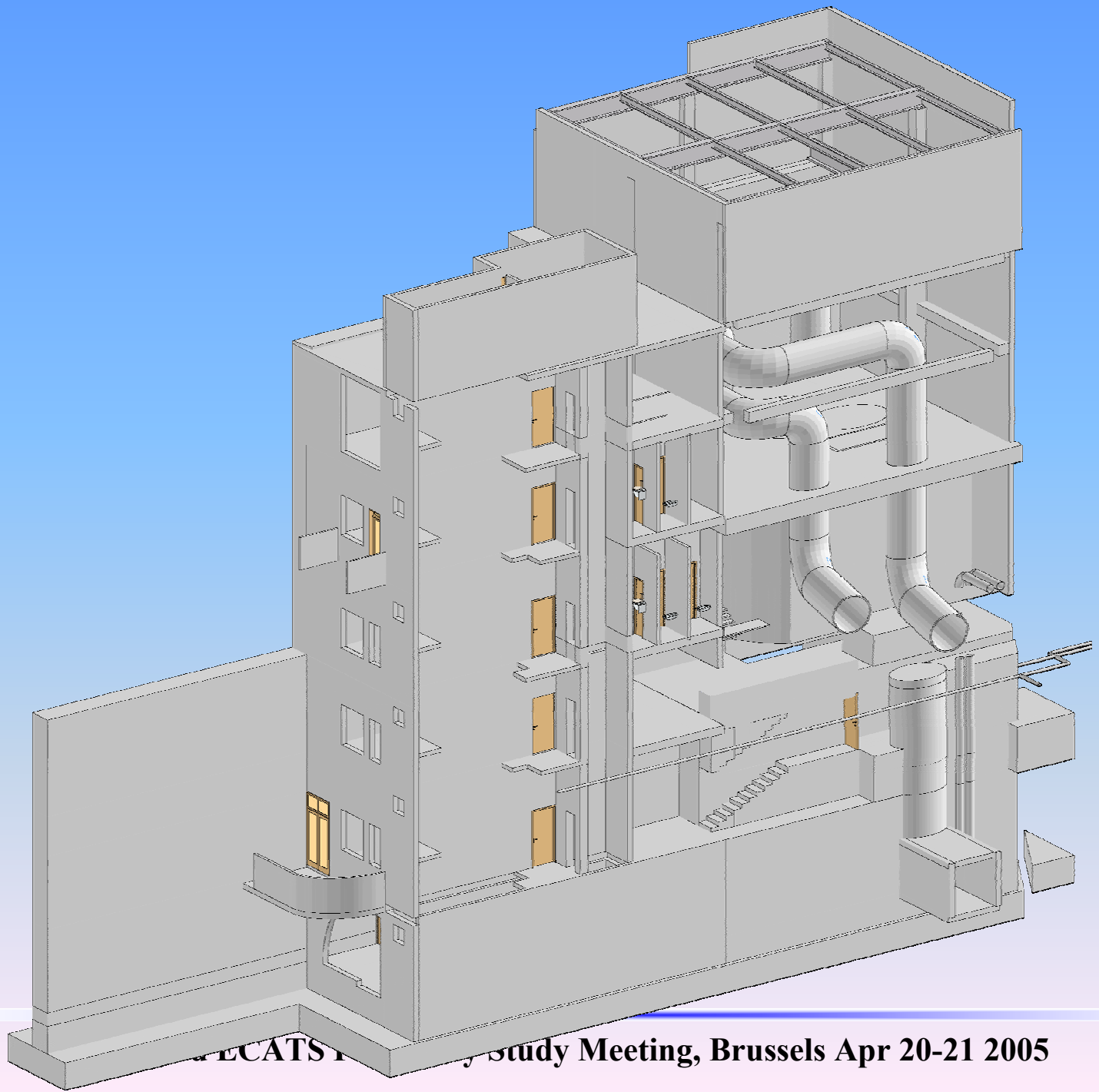
General Layout

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

РАЗРЕЗ
2 – 2


состав кровли см. разрез 1–1 лист 9
стальная пожарная лестница
стальная пожарная лестница
стальная пожарная лестница
+28.000
+27.000
+23.000
+18.400
+15.000
+10.000
+8.500
−0.500
−2.500
−4.000
+25.900
+22.300
+18.700
+15.100
+10.900
+7.500
+3.700
+0.700
+0.950
+19.000
+15.000
+8.500
−0.500
(123.35)
32/5
Ø3600
1 500
двойной пол
300
подвесной потолок
наружная грань стены здания 4
8 000
6 500
9 000
2000
3 300
3 600
3 600
4 200
3 400
3 800
3 000
1 000
2 600
1 900
1 500
2 100
1 500
2 400
1 500
2 100
1 450
2 100
1 500
1 800
2 000
400
2 200
1000
25 900


РАЗРЕЗ
1 — 1
слой гравия, втопленного в битумную мастику – 10 мм
2 слоя филизола (ТУ 5774–008–05108038–99)
цементно–песчаный раствор марки 100 – 20–80 мм по уклону
плиты минераловатные повышенной жесткости (ГОСТ 22950–95) 200 кг/м3 – 100 мм
монолитная железобетонная плита – 200 мм
стальная пожарная лестница
+32.300
+29.200
+28.000
+27.000
+25.900
+23.000
+22.300
+20.000
+15.000
+14.400
+13.800
+13.500
+11.800
+9.800
+9.300
+8.700
+8.000
+7.350
+6.700
+4.600
−0.500
(123.35)
−1.500
−2.500
−2.400
−4.000
32/5 т
3 000
3 100
5 100
600
5 700
2 000
15 500
14 300
10 900
7 200
1000
2000
Ø1600
2 700
1200
2 250
3 300
центр активной зоны
наружная грань стены лаборатории ЯСНАПП
наружная грань стены здания 1
ось протонного пучка
фундаментная плита здания ЯСНАПП
фундамент здания 1
3 000
5 500
700
6 200
9 500
8 400
8 000

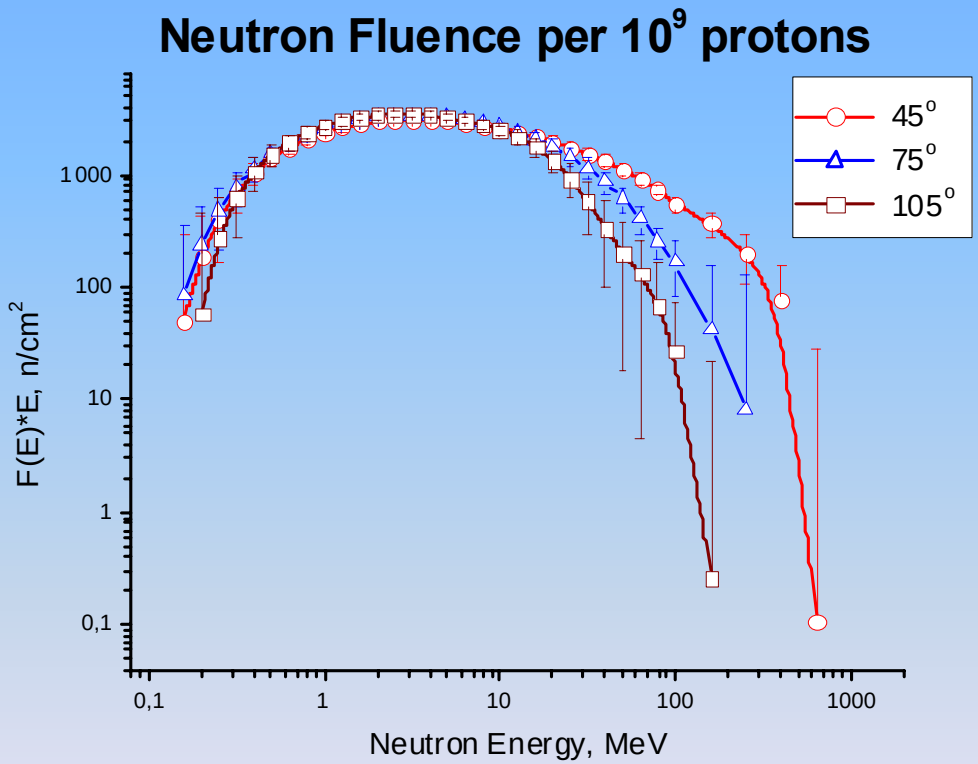


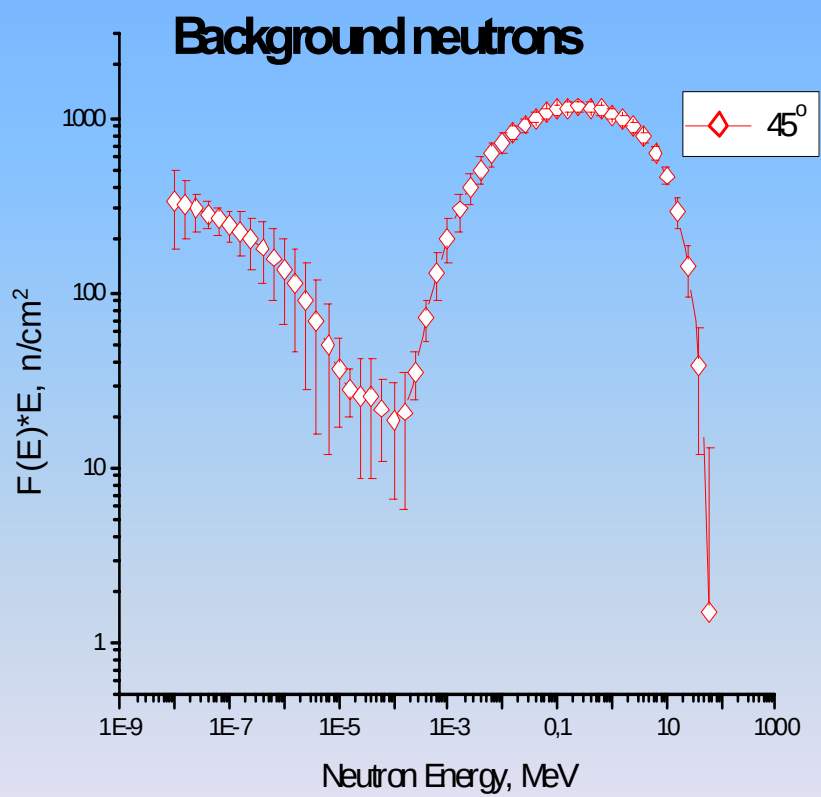
Project Status

- 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)

SAD related experiments (few examples)





SAD related experiments (few examples)

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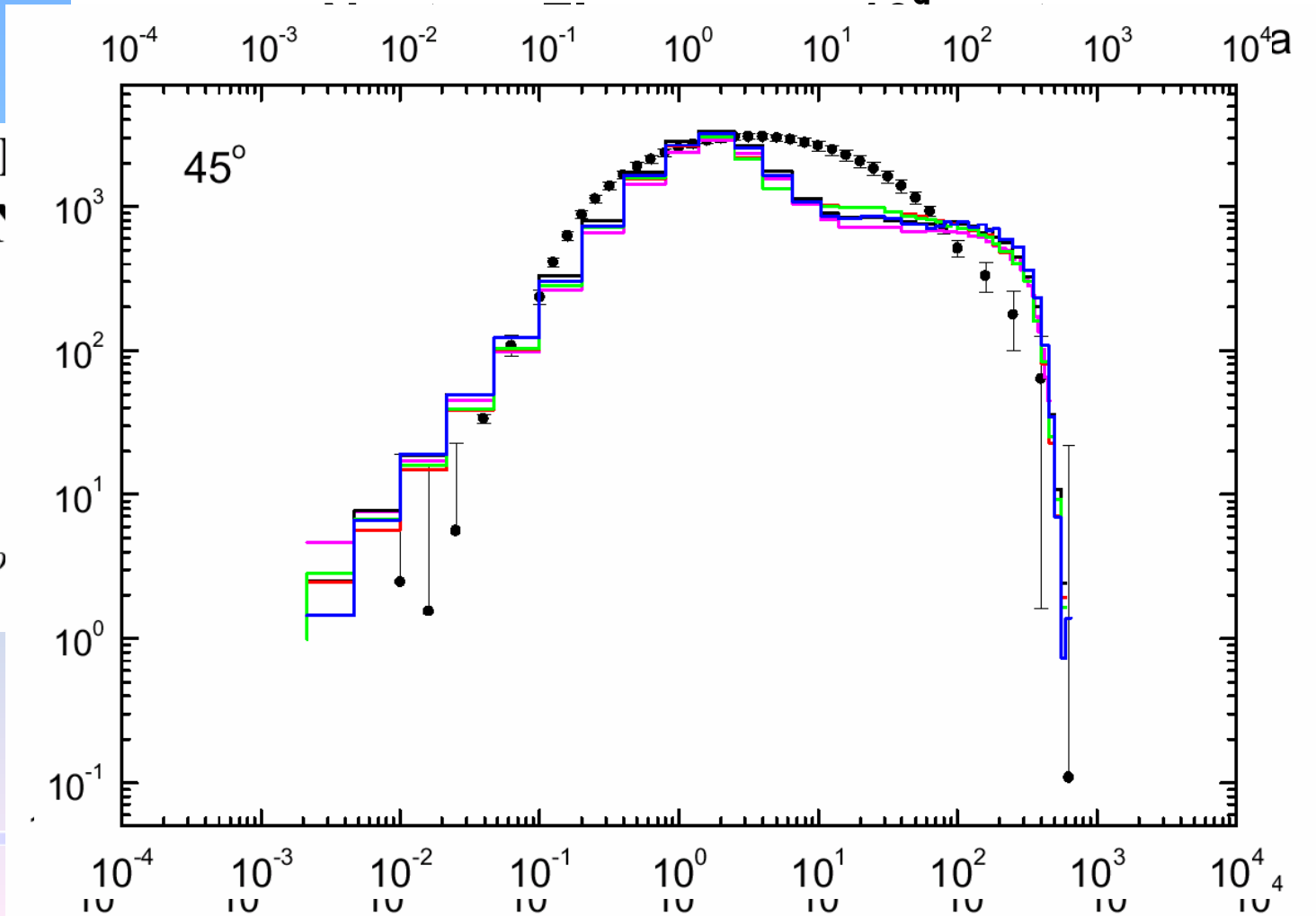
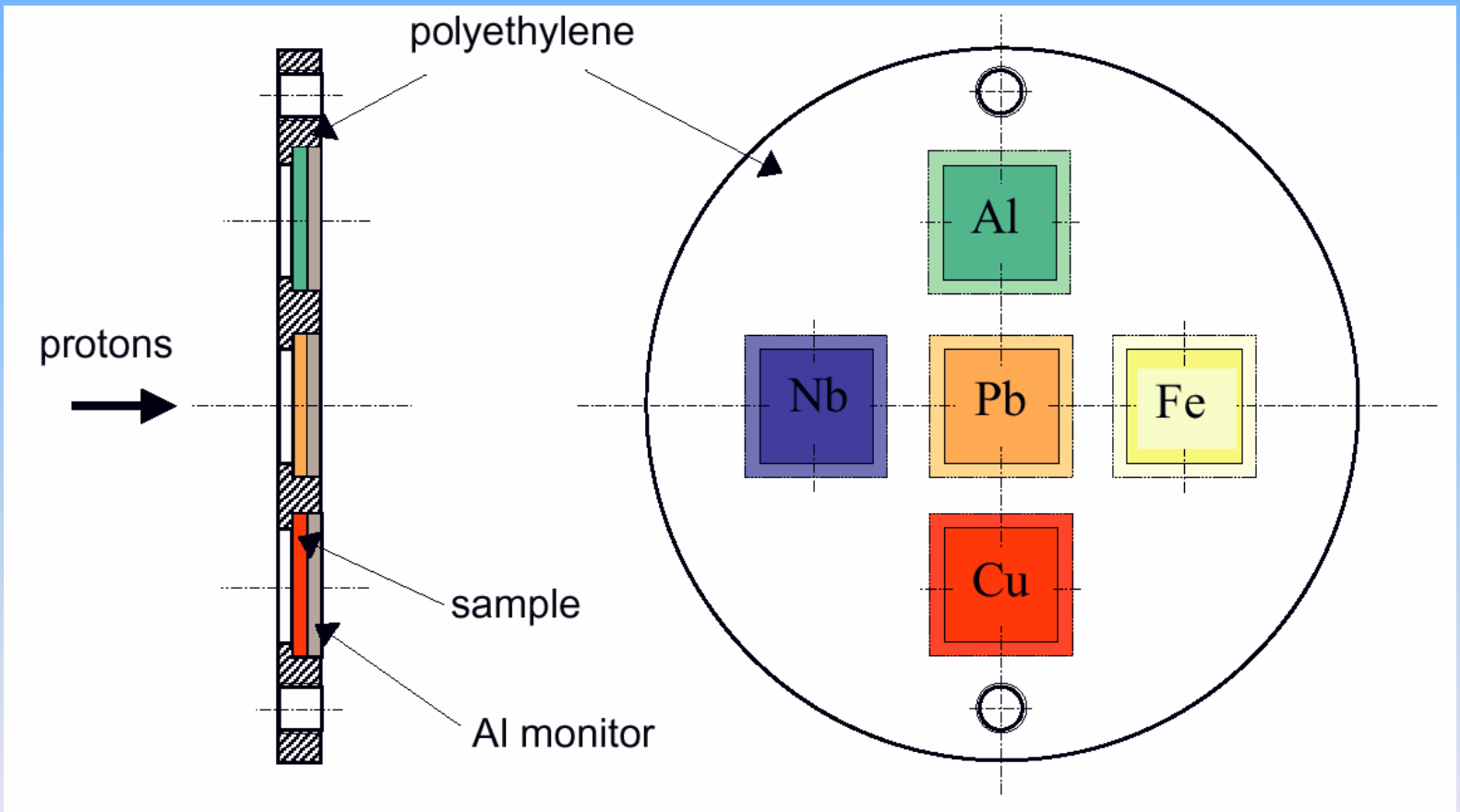


SAD related experiments (few examples)



Spallation products yields, experiments at Dubna

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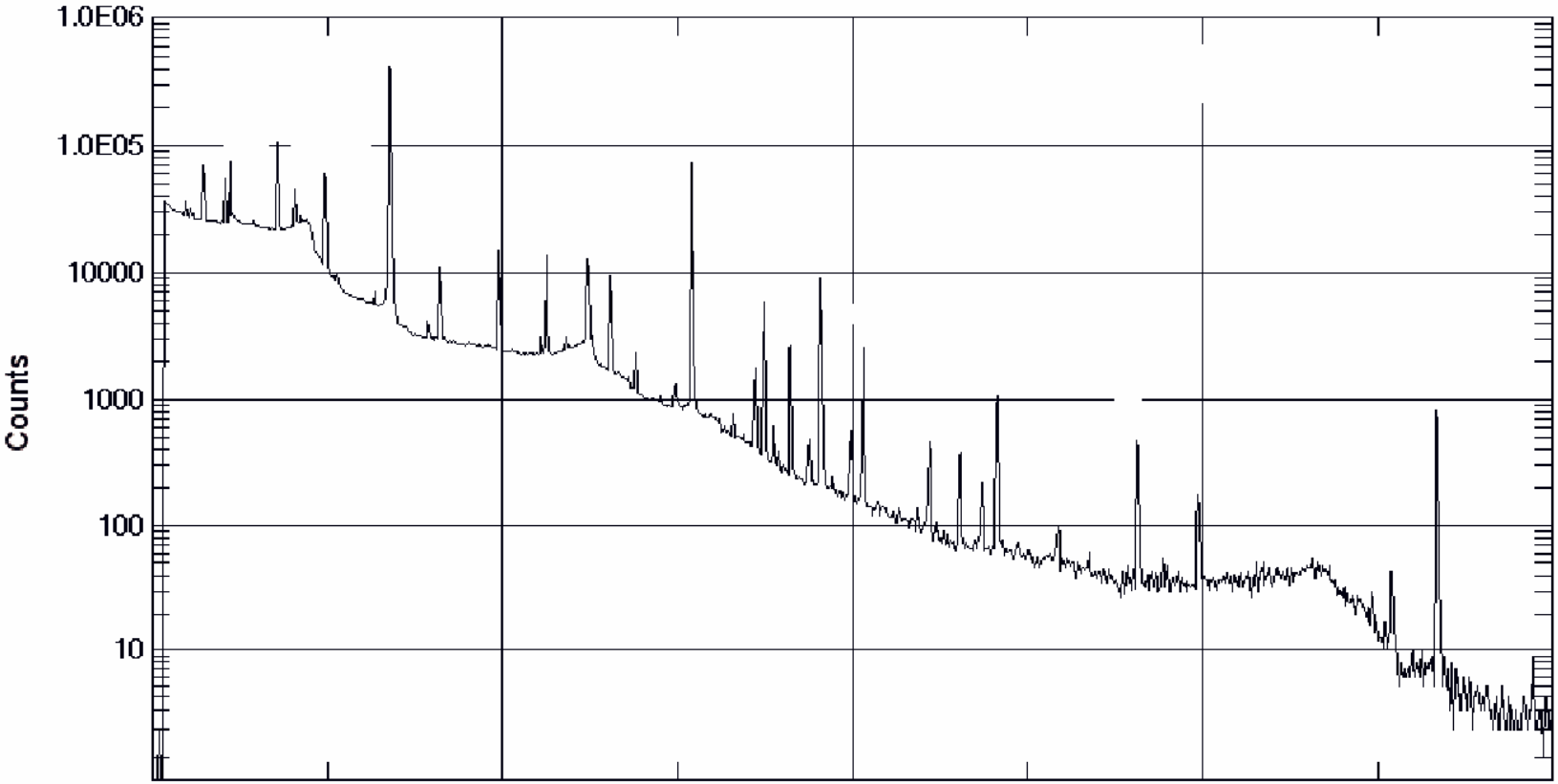
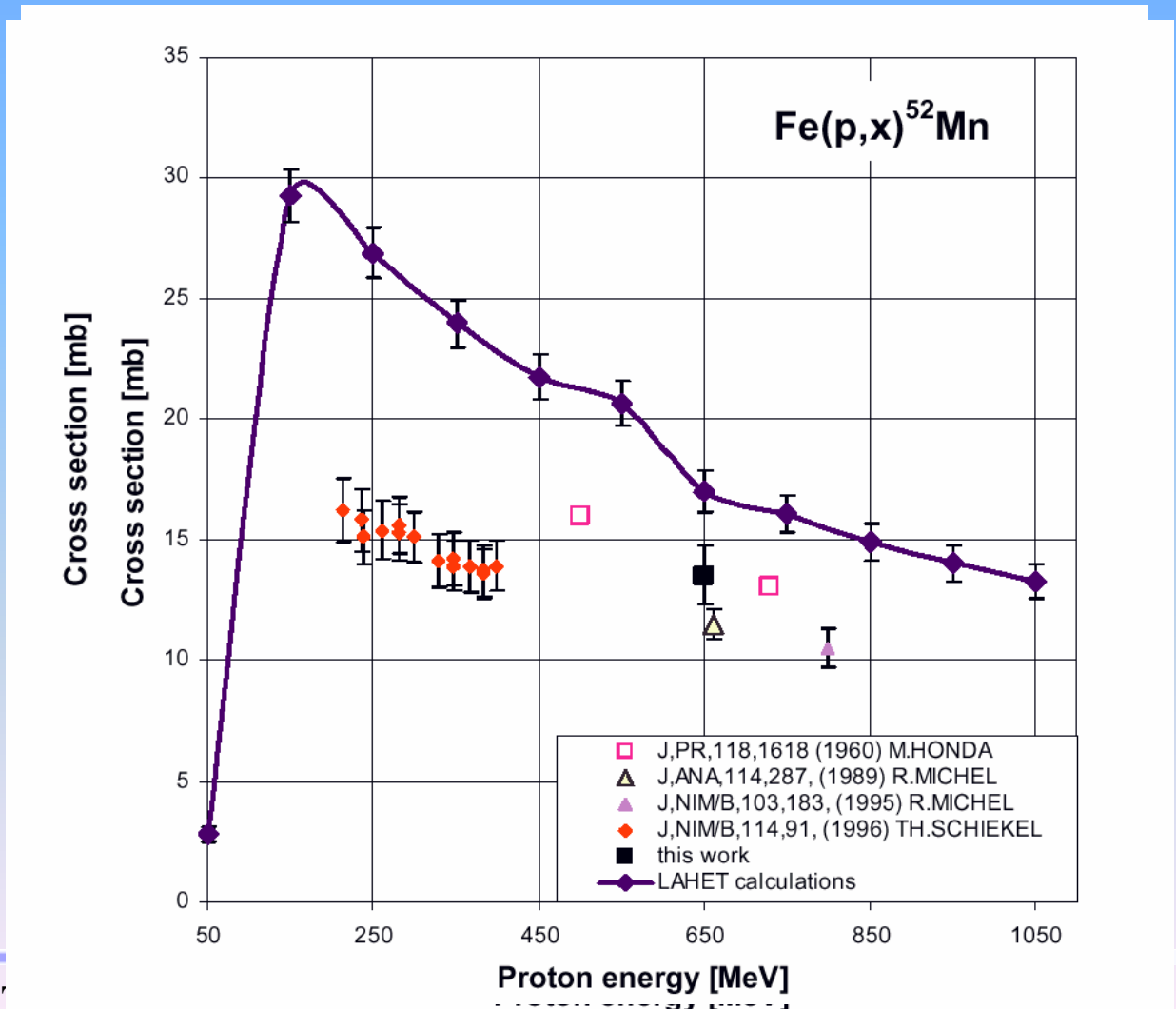
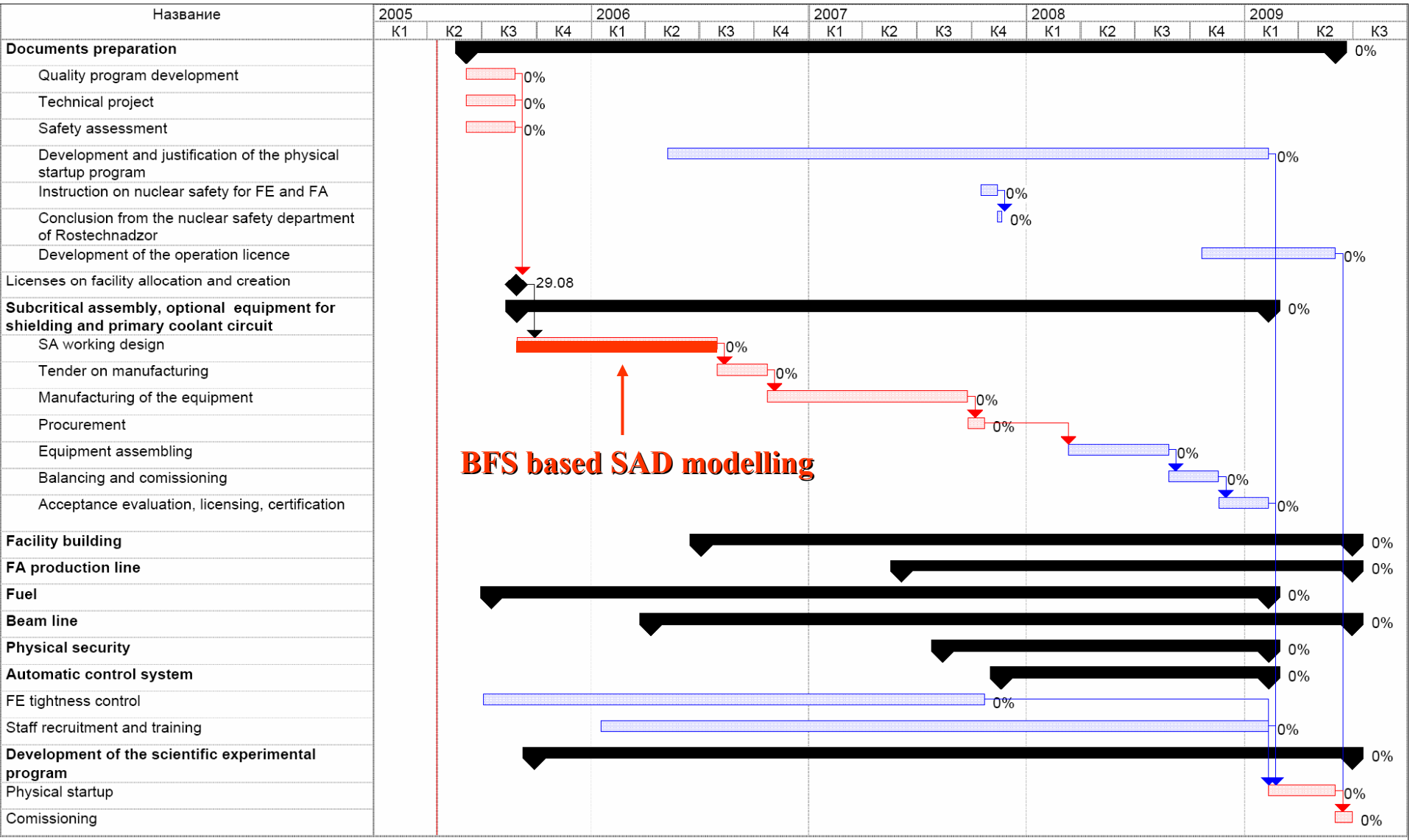


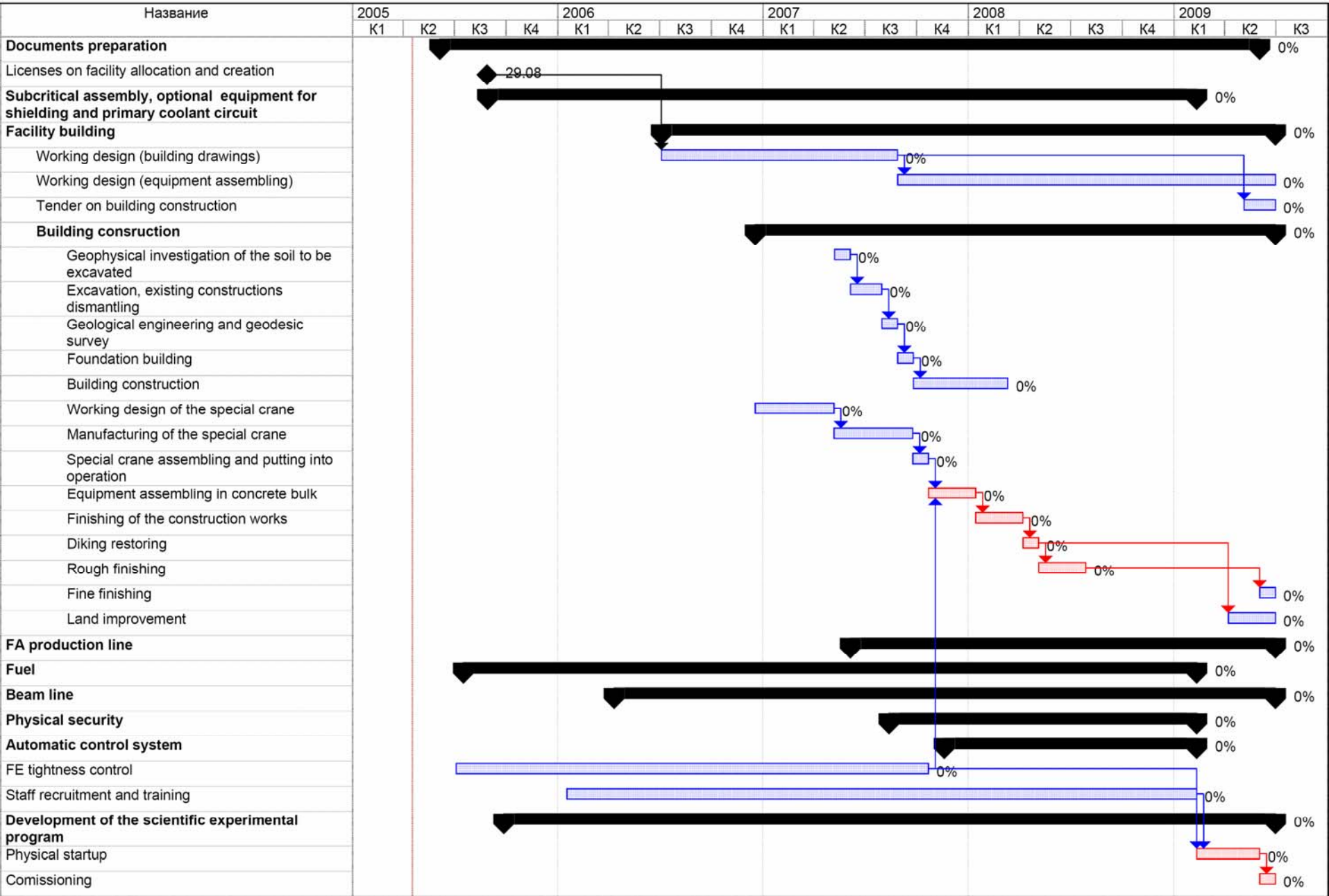
Spallation products yields, experiments at Dubna



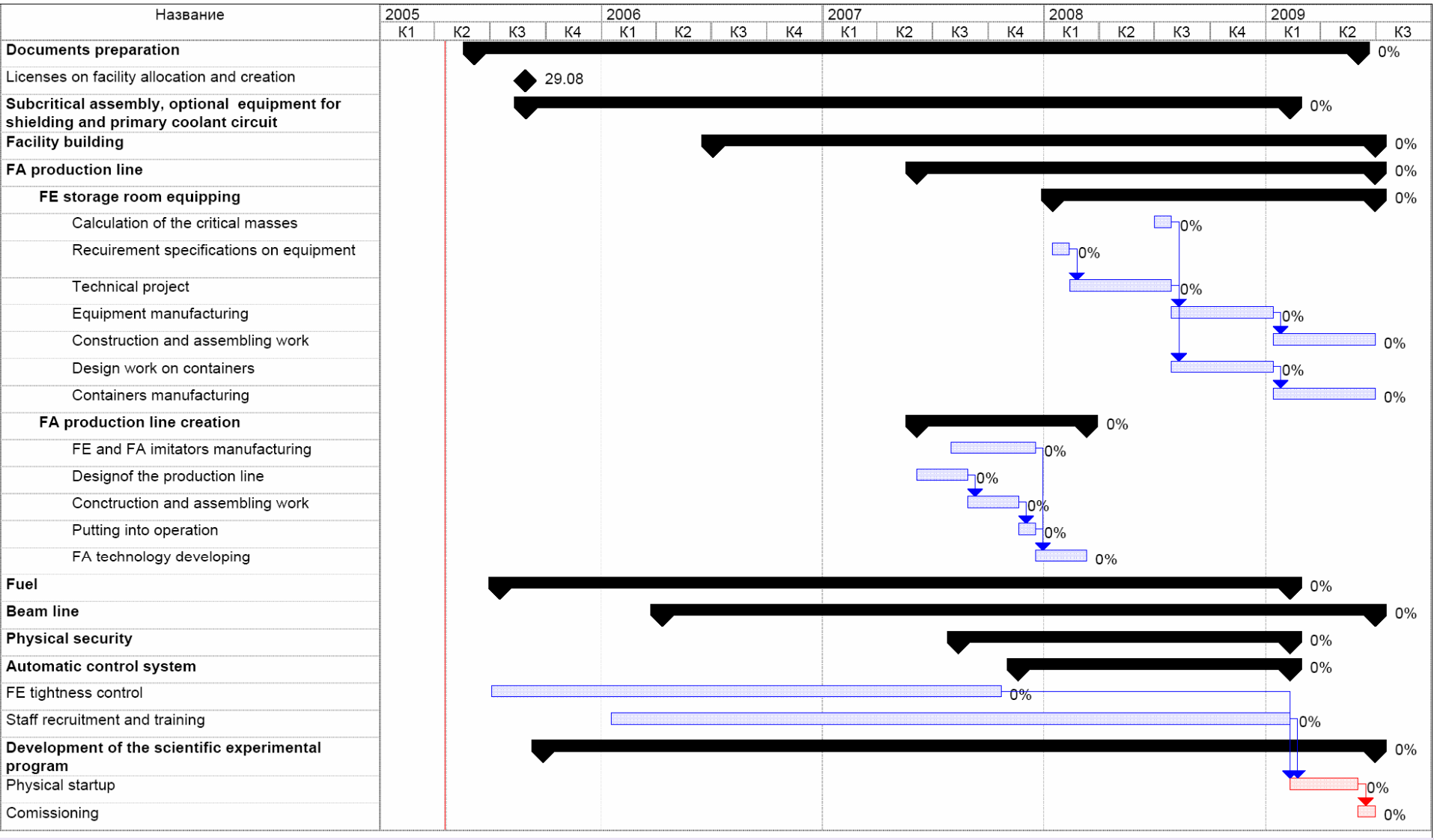
Project Timeline/licensing, blanket/



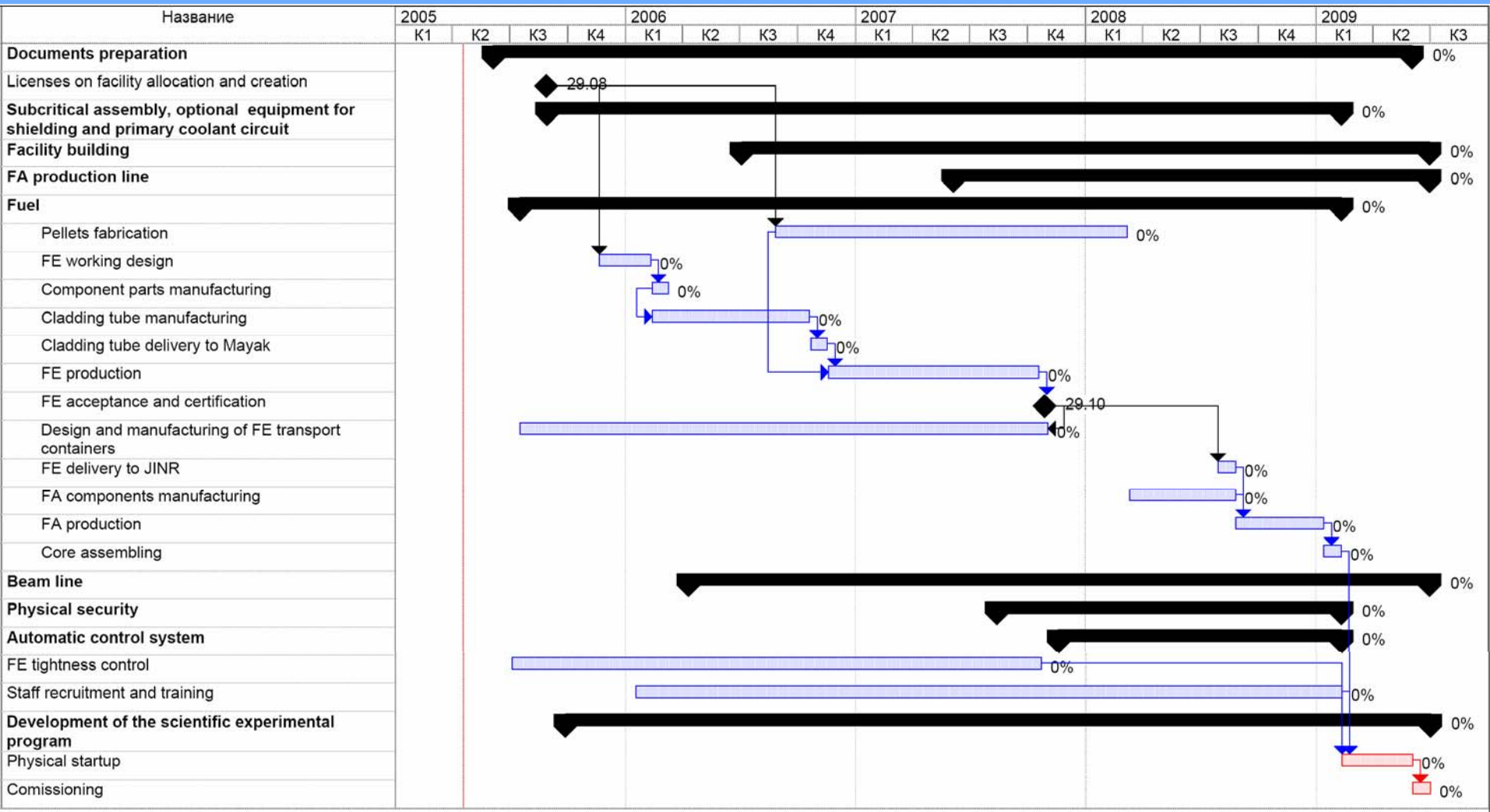
Project Timeline /building/



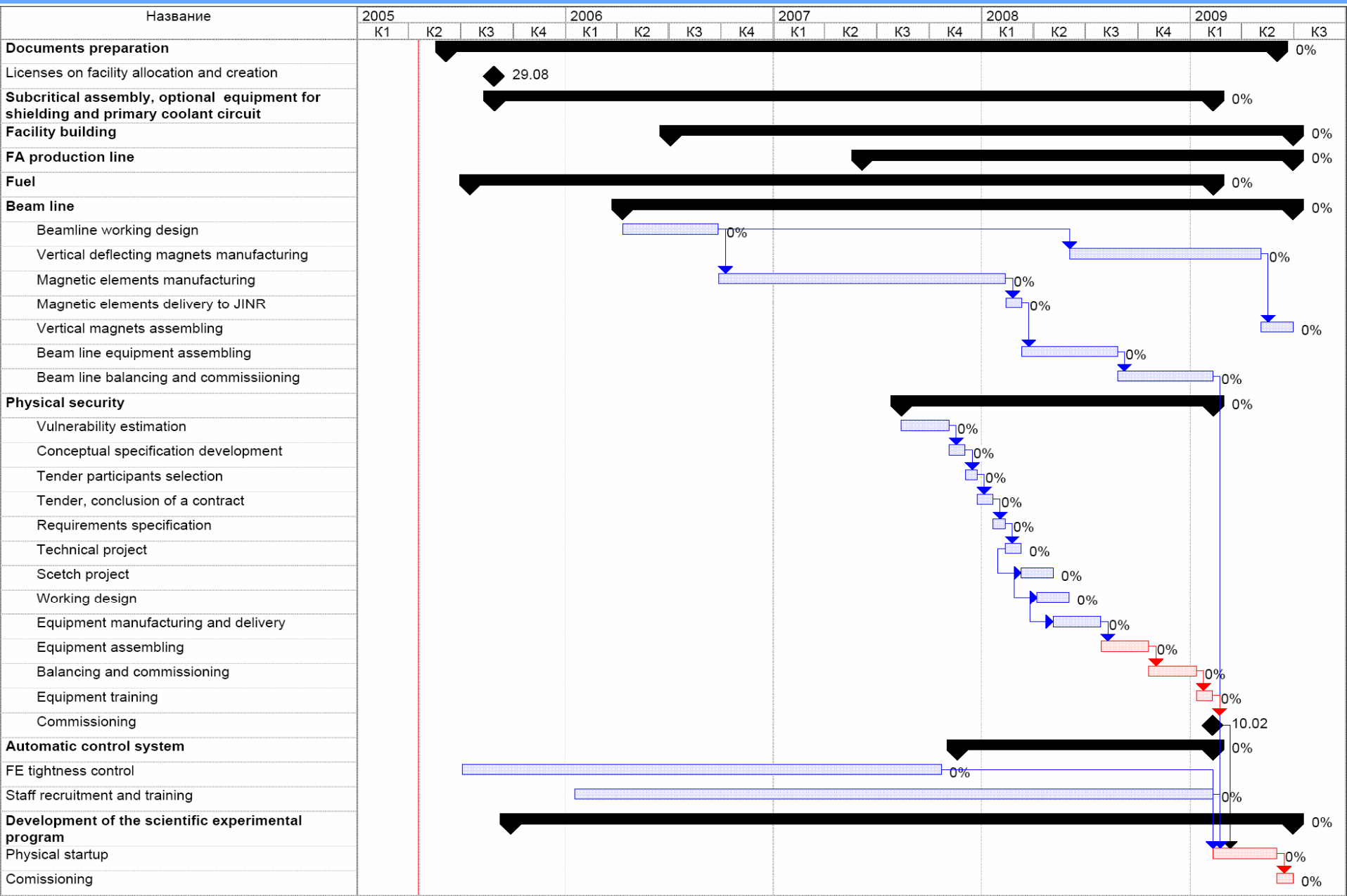
Project Timeline /FA production line/



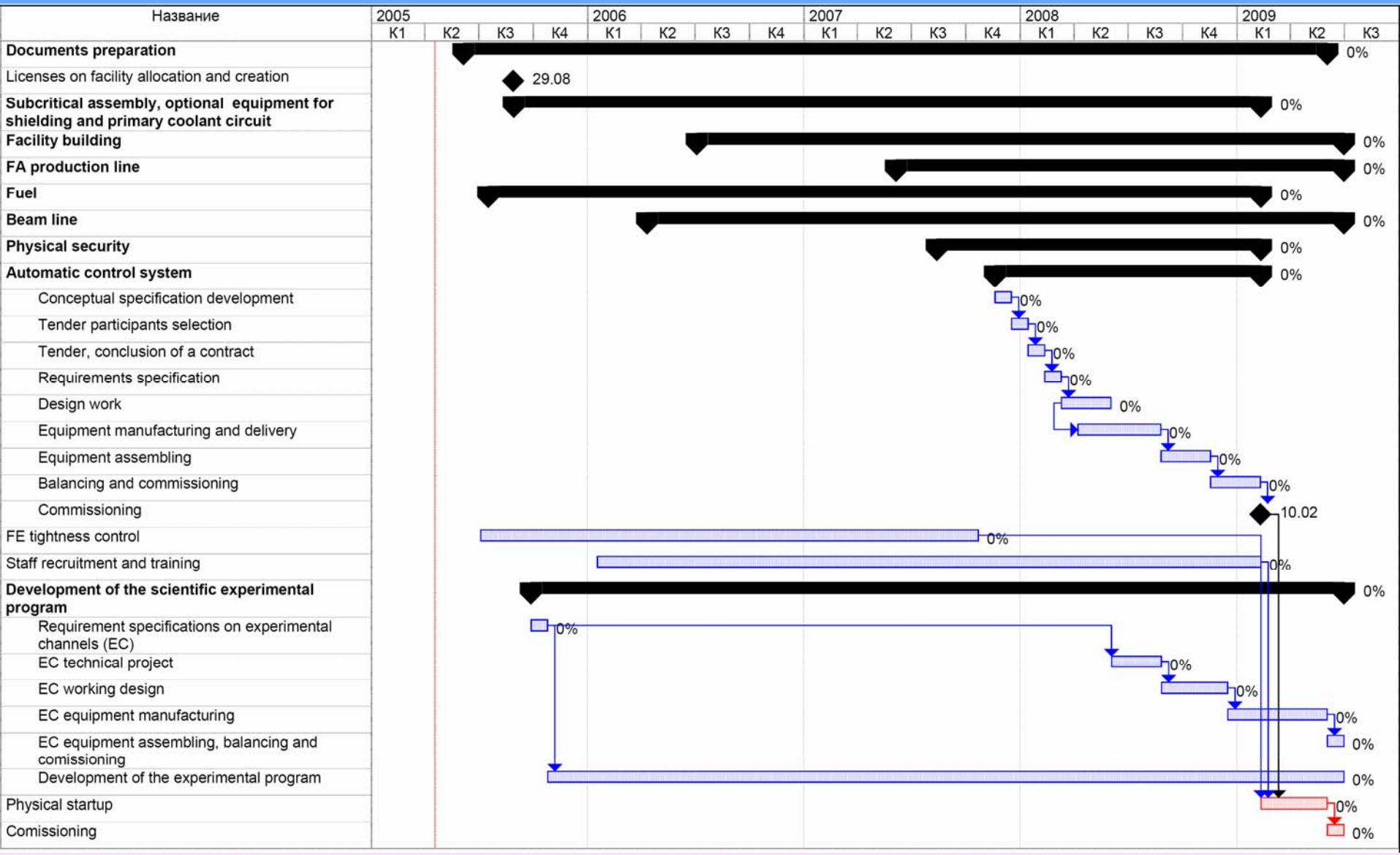
Project Timeline /fuel elements/



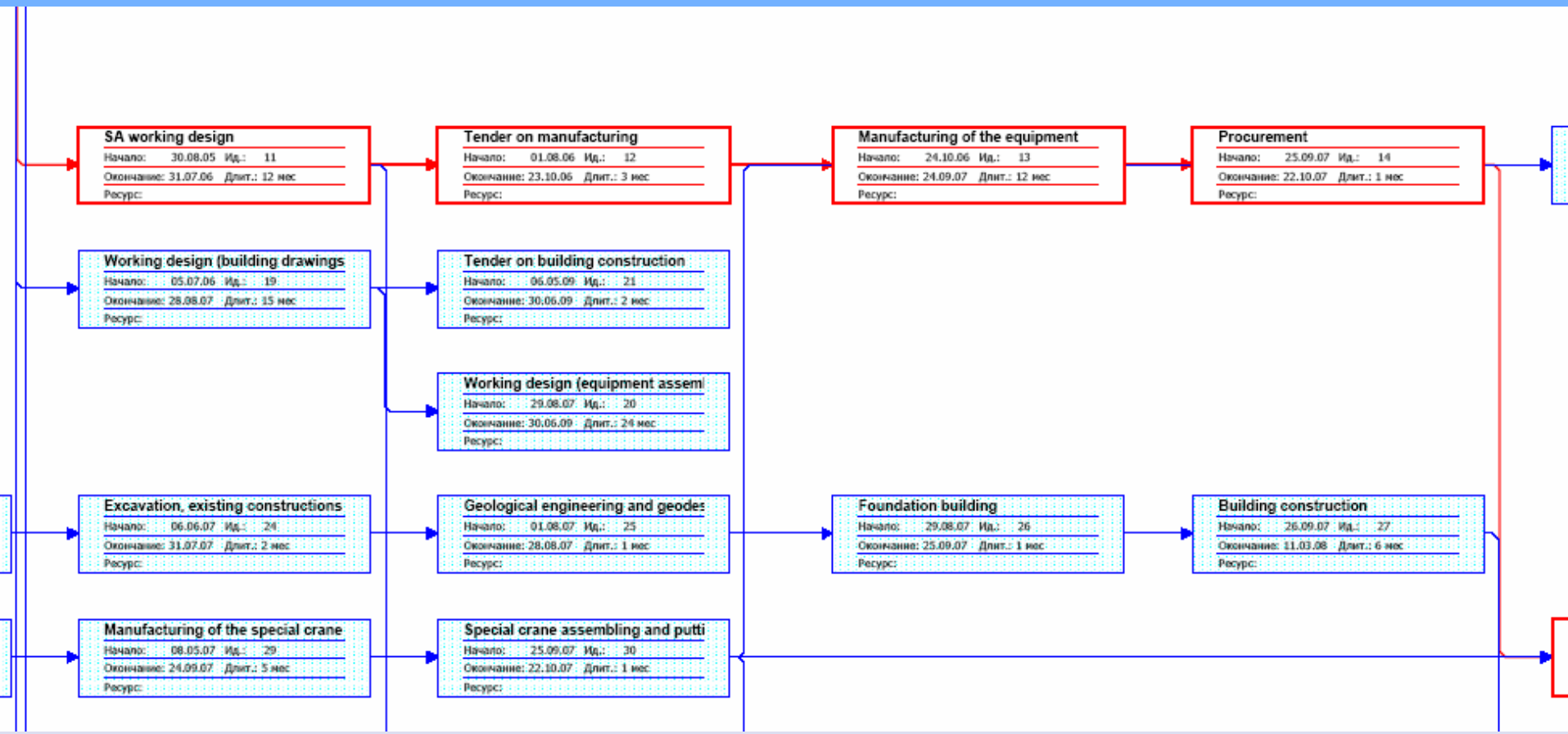
Project Timeline /beam line & phys. sec./



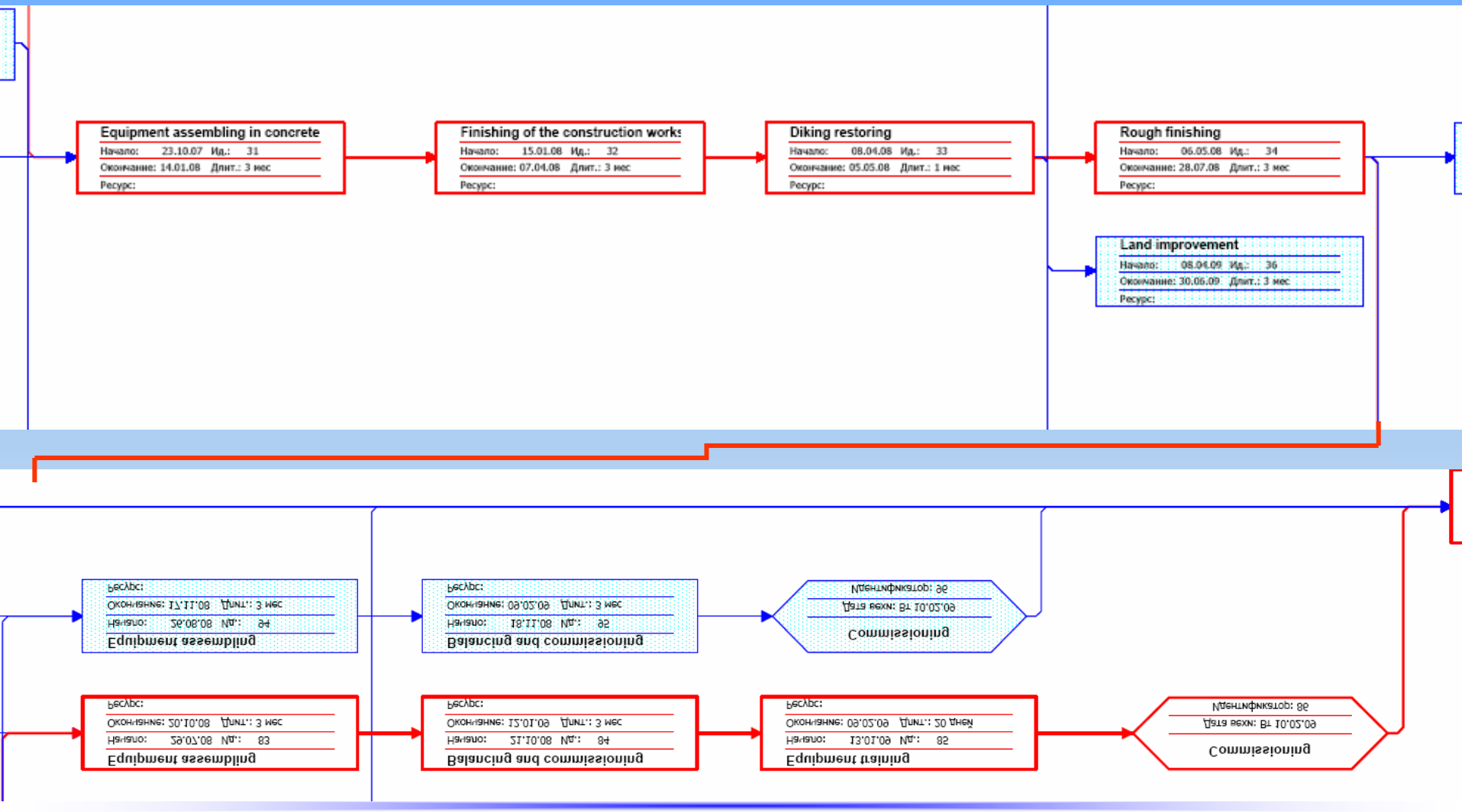
Project Timeline /ACS & exp./



Project Timeline /crit. path: blanket/



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



Cost assessment