

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

Second ECATS meeting

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

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1- JINR

2 – VNIINM

3- GSPI

4 - NIKIET

5 - IA “Mayak”



International Intergovernmental Organization

Joint Institute for Nuclear Research



JINR: INTERNATIONAL SCIENTIFIC CENTRE BRINGING NATIONS TOGETHER

BIRLASHMIS NUVV TADQIQATLARI INSTITUTU
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 ОБИДВЕНЕН ИНСТИТУТ ЗА ЯДРЕНИ ИЗСЛЕДОВАНИЯ
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 核研究国際研究所
 INSTITUTO UNIFICADO DE INVESTIGACIONES NUCLEARES

INSTITUTUL UNIFICAT DE CERCETARI NUCLEARE
 ЦЕНТРИЙН ШИНЖЛЭГЭЭНИЙ НЭГДСЭН ИНСТИТУТ
 ZJEDNOCZONY INSTYTUT BADAŃ JĄDROWYCH
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 INSTITUTUL UNIFICAT DE CERCETARI NUCLEARE
 SPOJENÝ ÚSTAV JADROVÝCH VÝZKUMOV
 ЯДРОВНИЙ ТАДҚИҚОТЛАР БИРЛАШҚАН ИҢСТИТУТИ
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 SPOJENÝ ÚSTAV JADERNÝCH VÝZKUMŮ

Co-operation with Germany

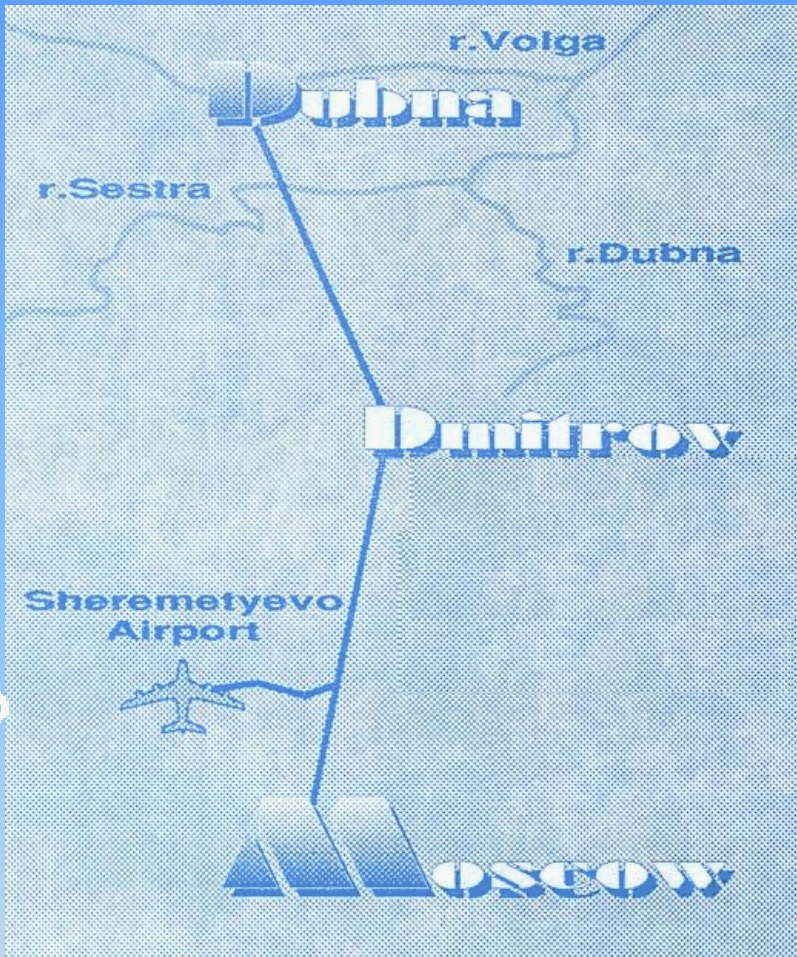
- **JINR's partners are**
 - **67 institutions located in 45 cities**
- **Research activities are regulated by the Agreement between BMBF and JINR concluded in 1991**



- **Location of centres collaborating with JINR**

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



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

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Basic Documents



26.03.1956:

Foundation of JINR

23.09.1956:

Adoption of the JINR Charter



1.02.1957:

JINR was registered by UN

23.06.1992:

Renewed Charter signed



24.09.1997:

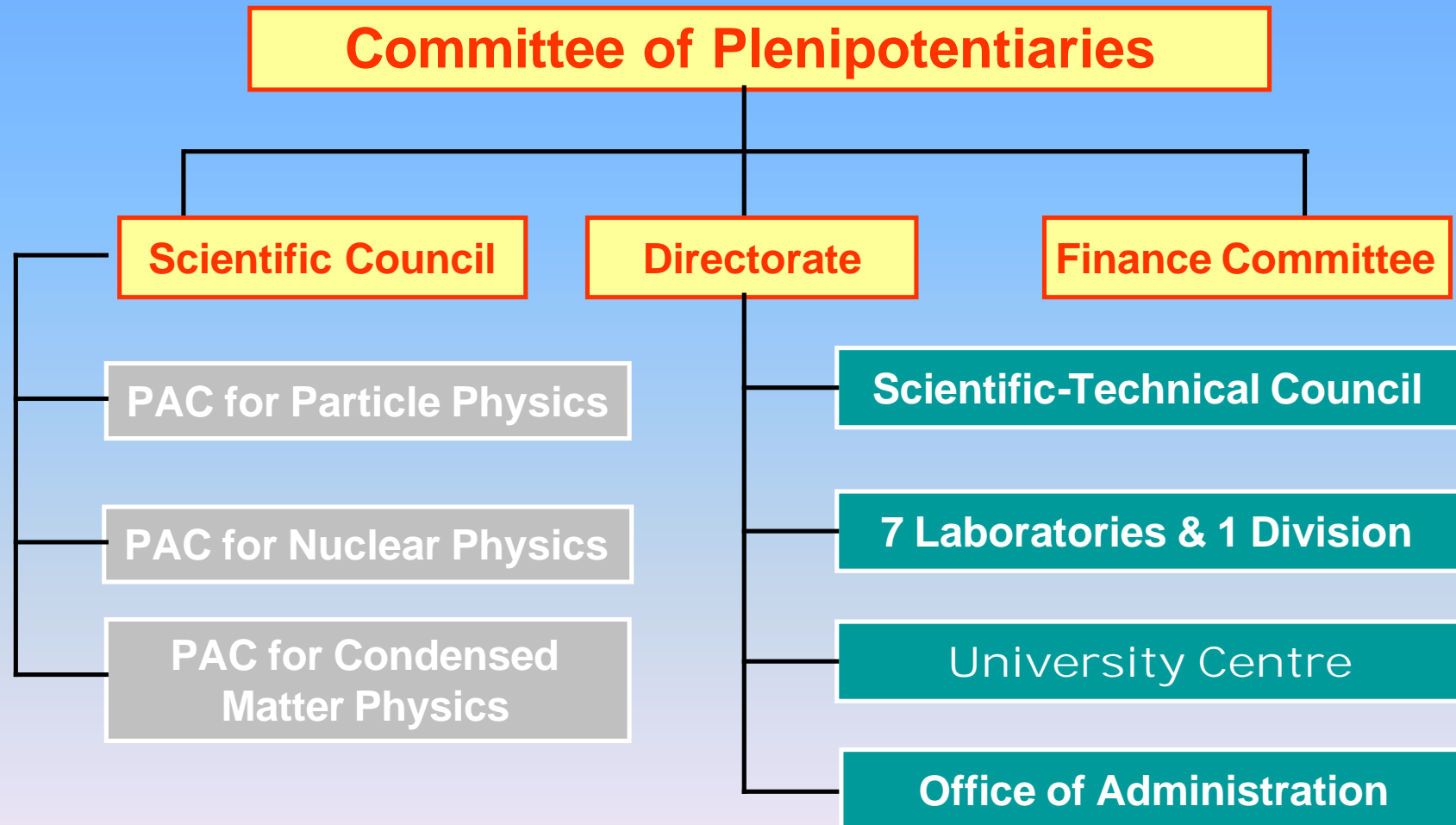
UNESCO – JINR Agreement



2.01.2000:

The Federal Law on the Russian Government – JINR Agreement

Governing Bodies & Structure



JINR Labs and Facilities



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;**

SAD Technical Description

(foreign collaborators)

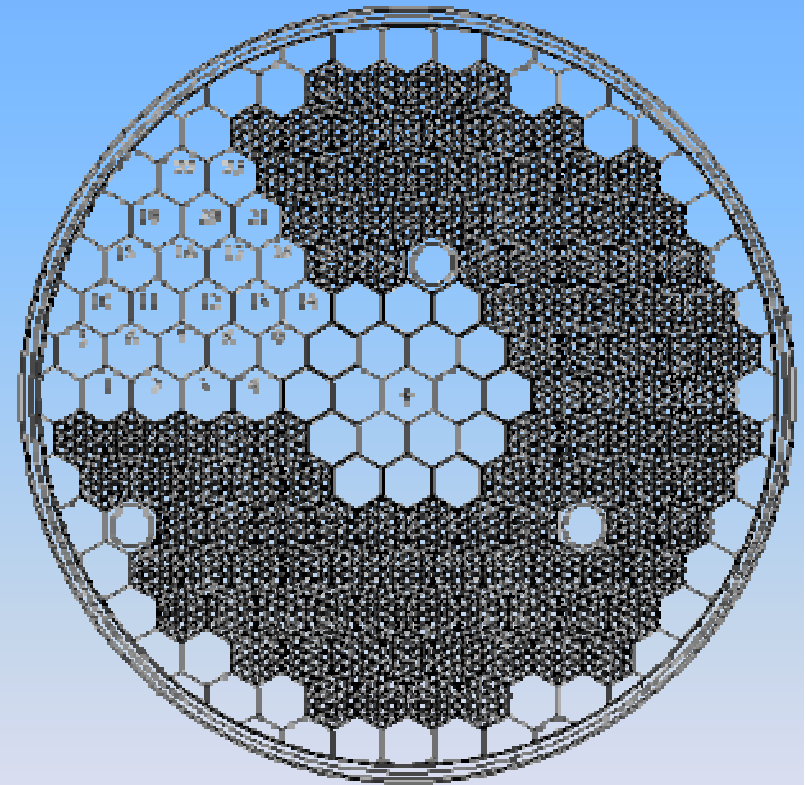
- ✿ Forschungszentrum Karlsruhe - FZK, Institut für Reaktorsicherheit, Dr. Cornelis Broeders;**
- ✿ Kungliga Tekniska Högskolan - KTH, Nuclear and Reactor Physics, Dr. Wacław Gudowski;**
- ✿ Centro de Investigaciones Energéticas Medioambientales y Technologies - CIEMAT , Dr. Enrique Miguel Gonzalez Romero;**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

Basic Data

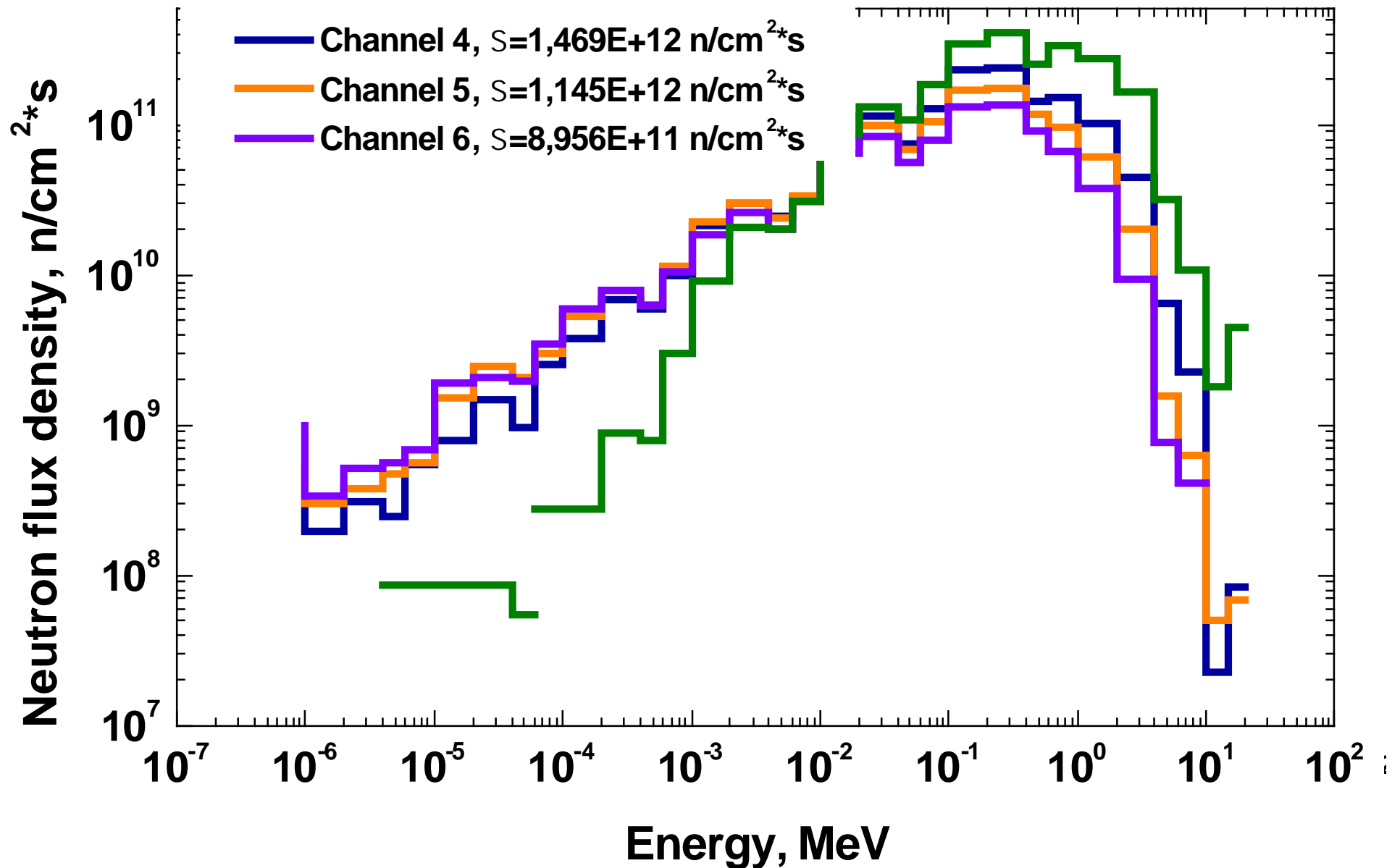
k_{eff}	~0,95
Fuel loading	< 420 kg
Fission power	27,6 kW
Cooling	air
Core	
Coolant flow rate, G	~ 0,6 kg/s
velocity, v	10 m/s
Pressure, P (<i>inlet</i>)	0,12-0,135 MPa
Temperature, T (<i>inlet, outlet</i>)	50/96 °C
Target (Pb)	
Coolant flow rate, G	~ 0,0067 kg/s
Velocity, v	50 m/s
Pressure, P (<i>inlet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

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/(\bullet m ² ·s)
Peak factor of heat generation (height)	1.21

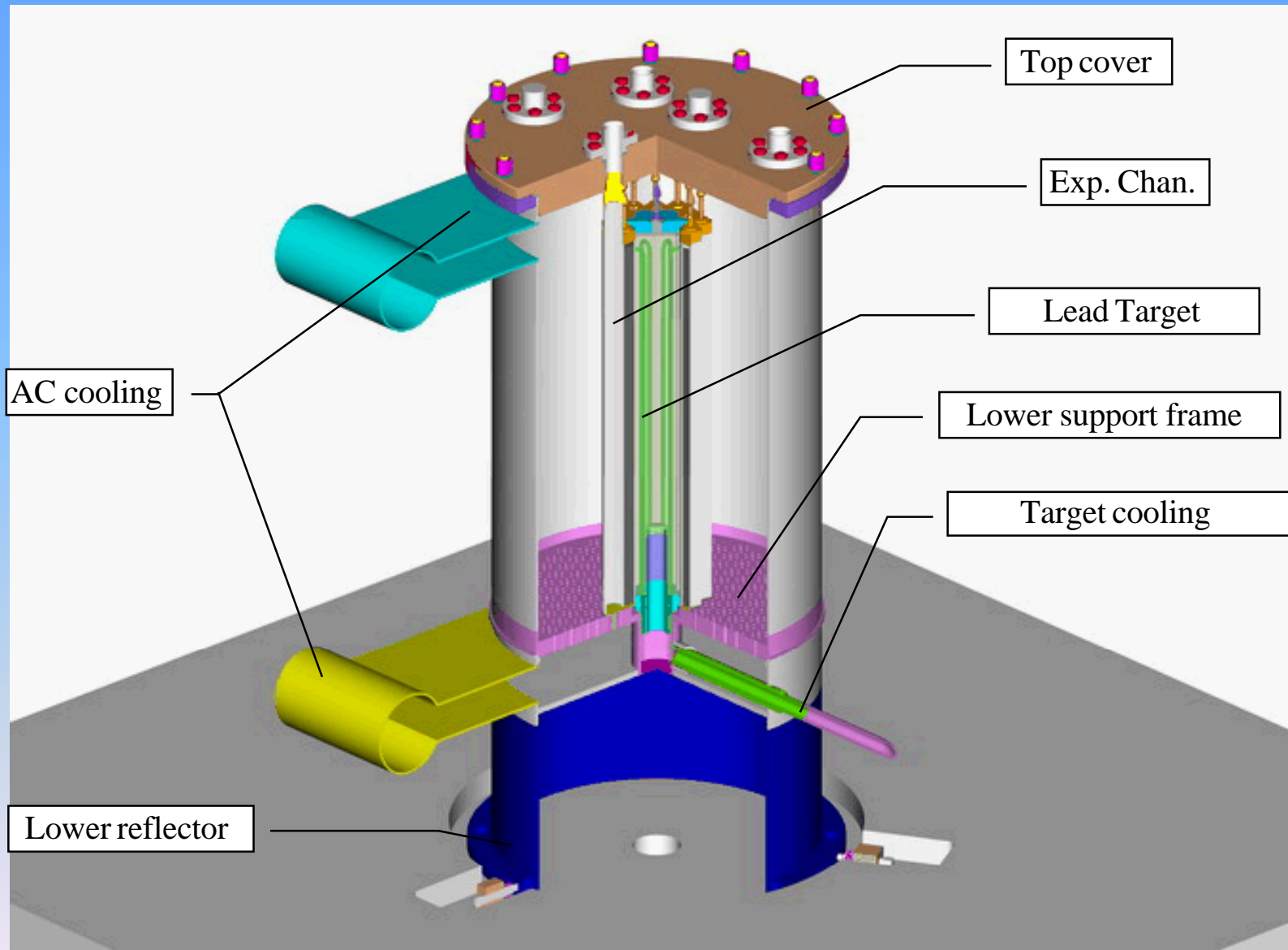
Heat generation in SAD parts :

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 ₄ C	204.6 W
Concrete	771.1 W
Pu decay	~250 W

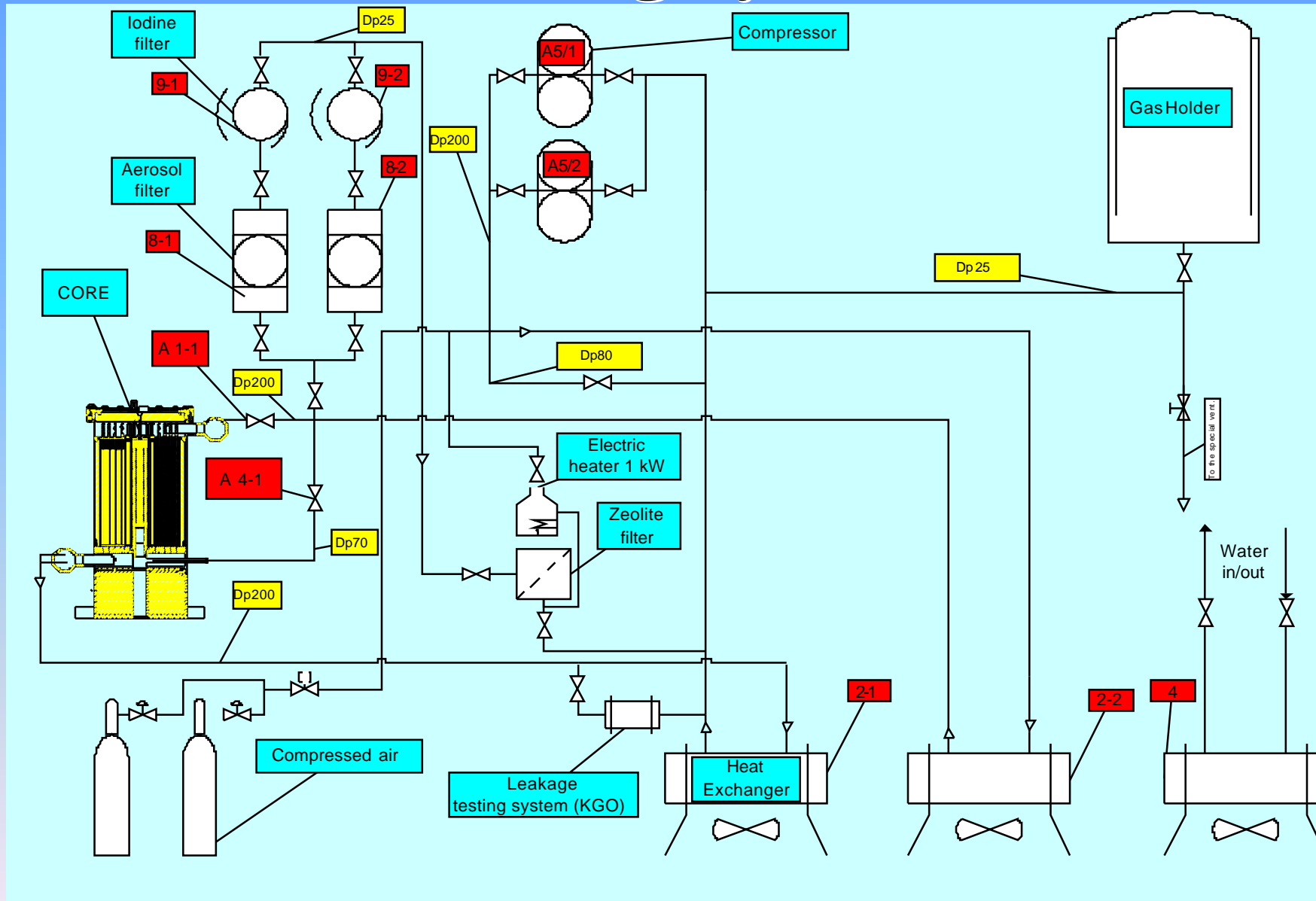
Fuel

Max power density	18 W/cm ³
Max flux of fast neutrons ($\bullet > 0,1$ 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

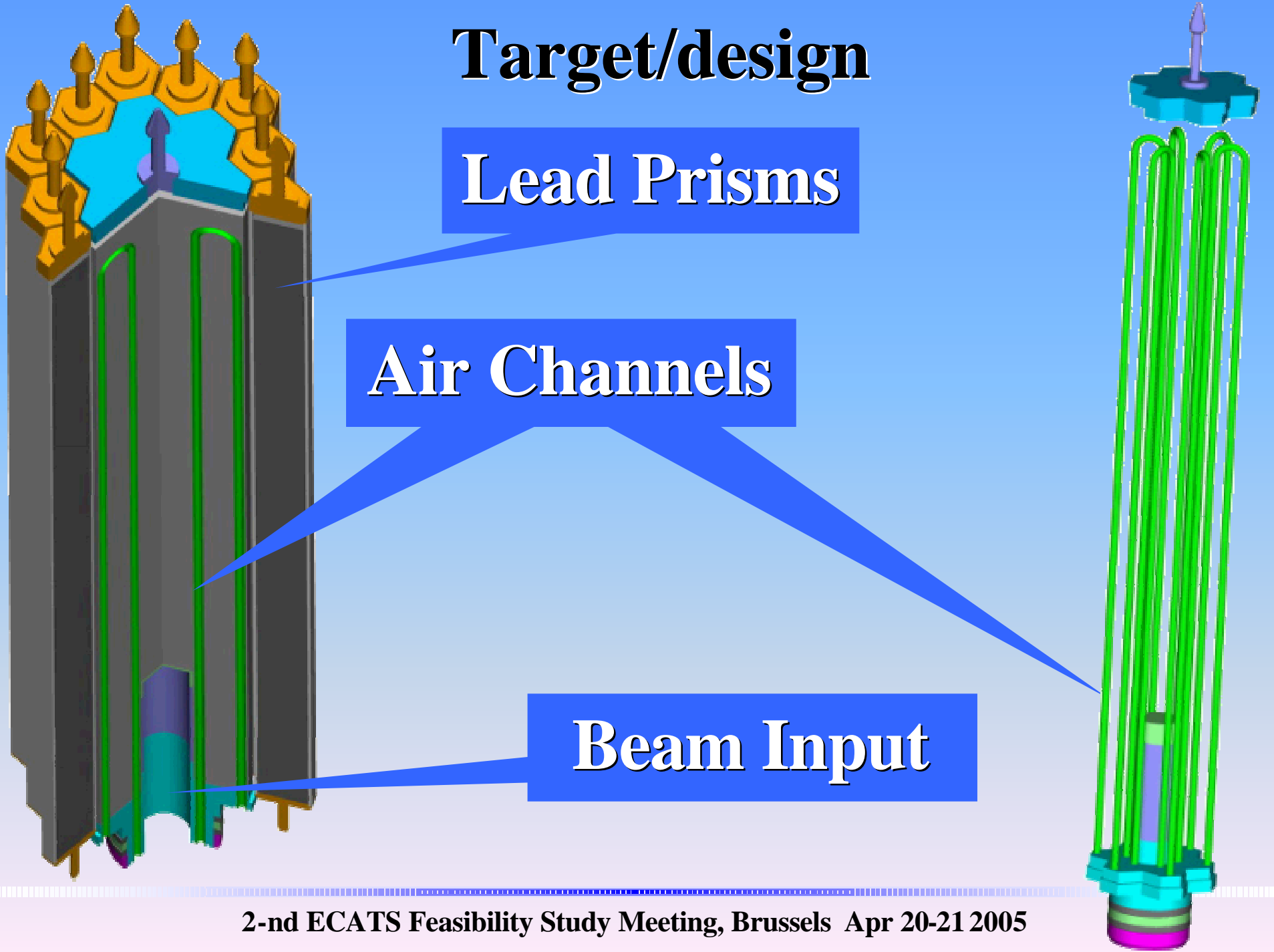


Target/design

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	1.143×10^{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) 4th 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 mA 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)

Phasotron Accelerator



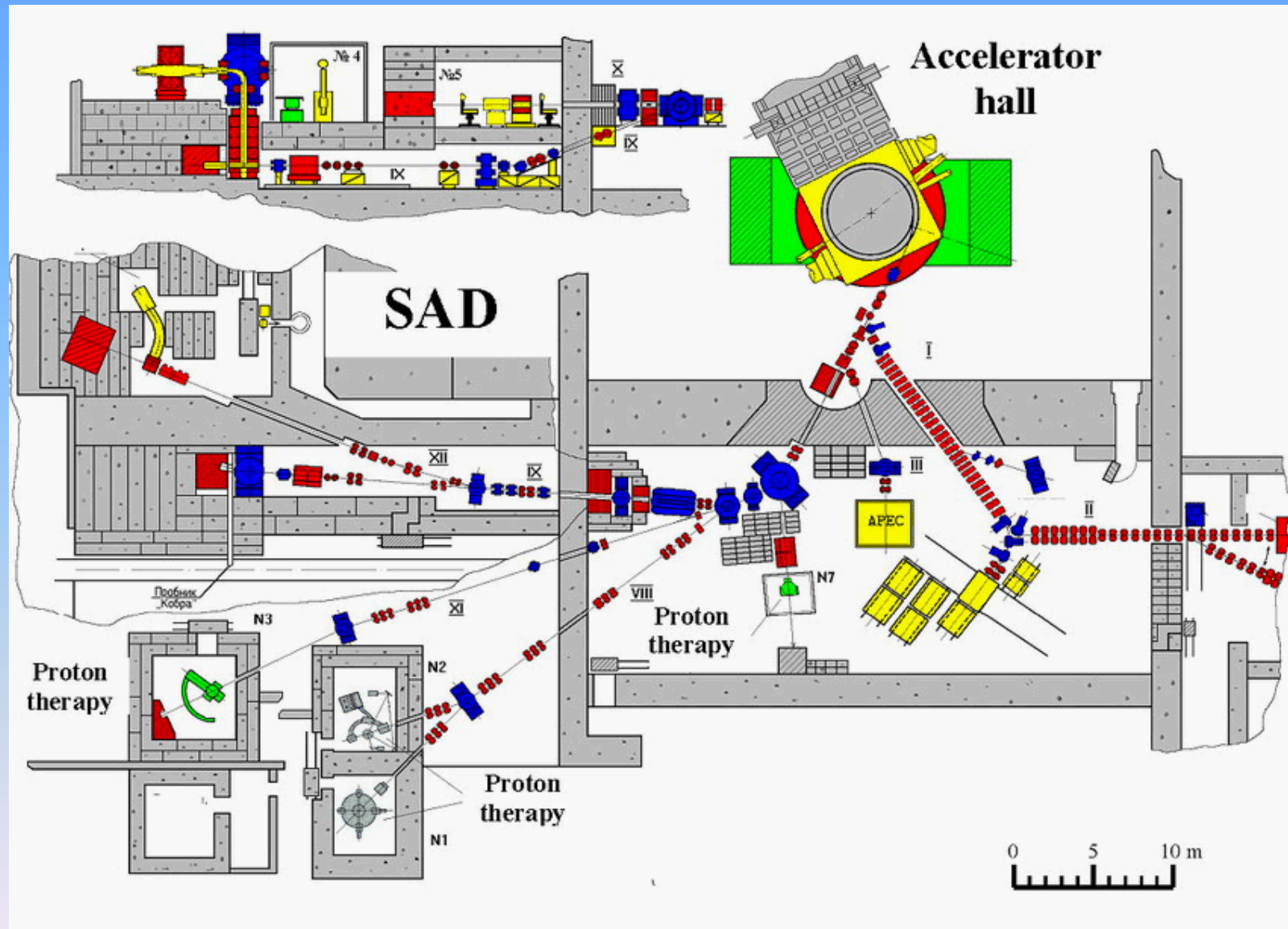
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Phasotron Accelerator



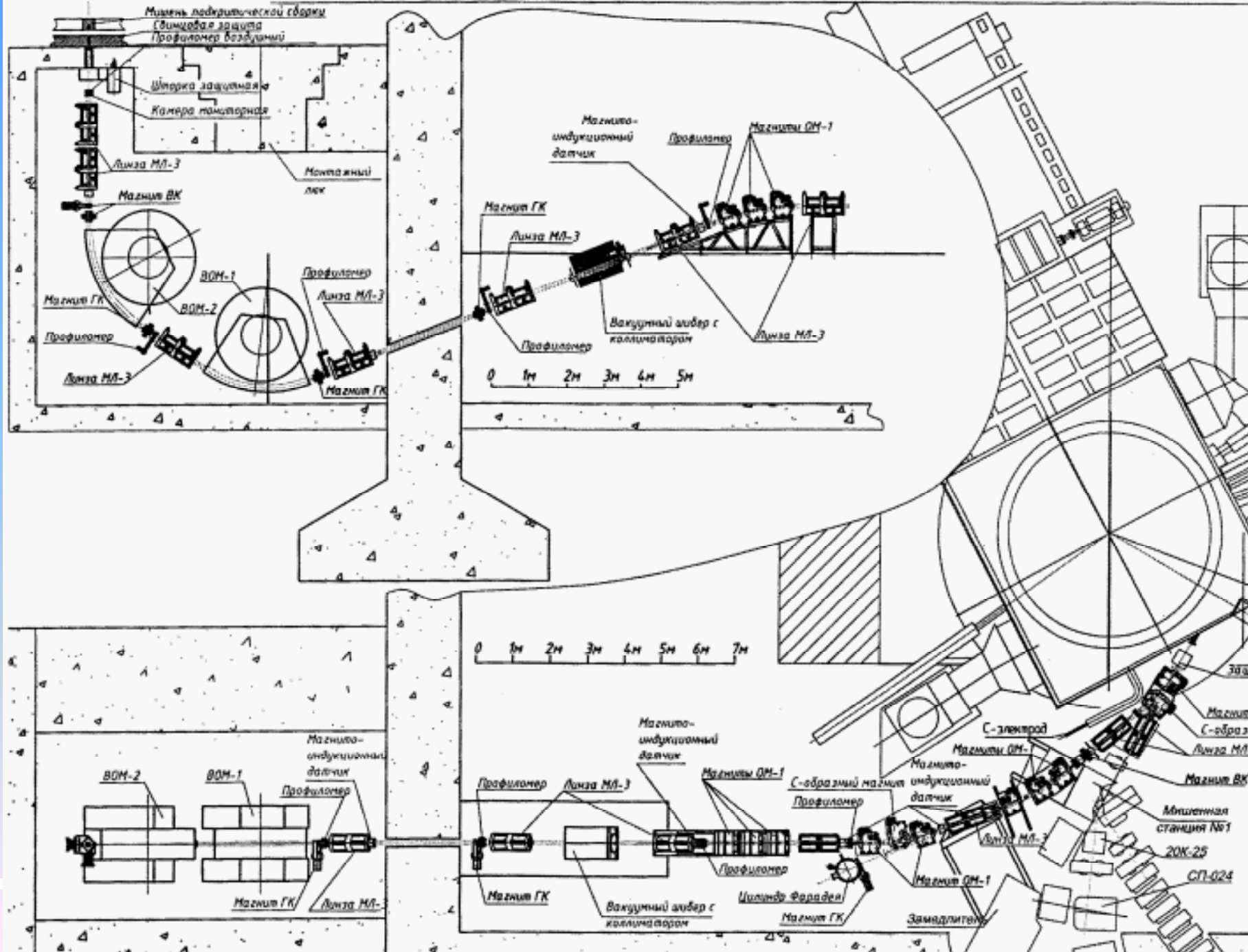
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Phasotron Accelerator



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Тракт транспортировки протонного пучка к установке SAD



Initial data for SAD FE design

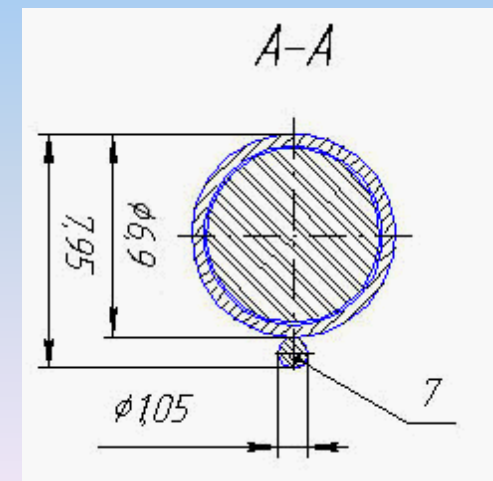
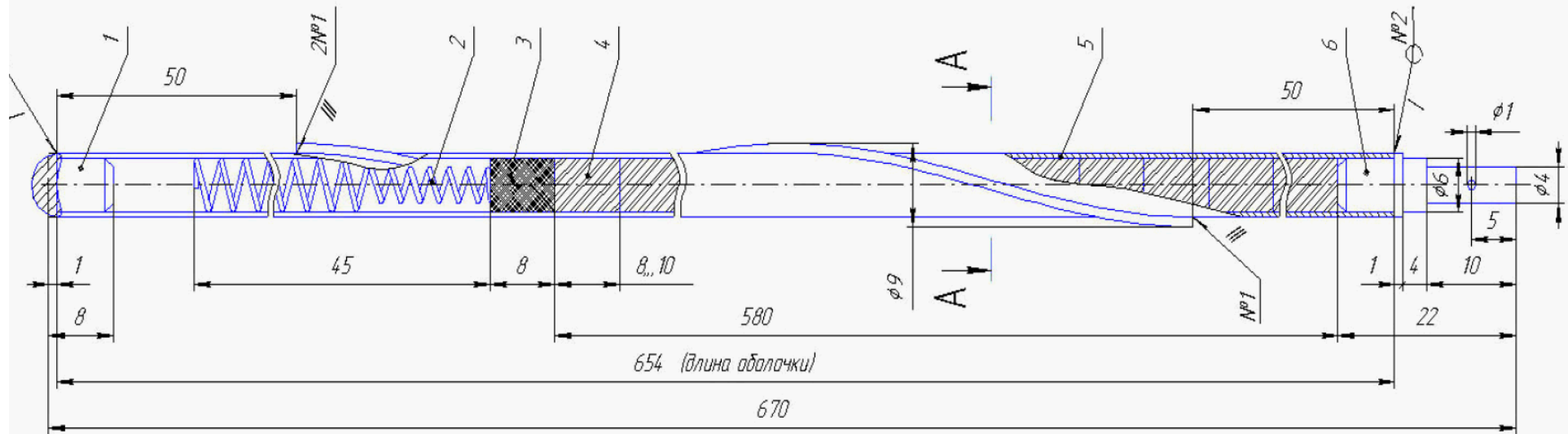
Operating Conditions

- ❁ 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° .
- ❁ Core Coolant - Dry, Dust-free Air.
- ❁ Maximum Coolant Temperature at Core Output - 125° .
- ❁ 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

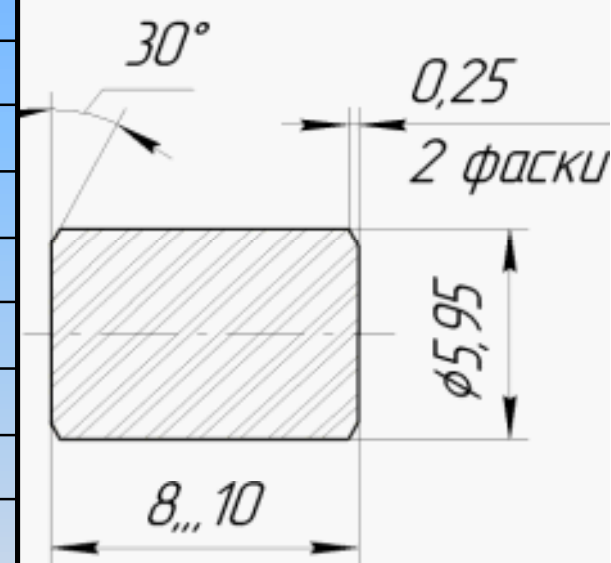
- ❁ Uranium and Plutonium Feed Powders, which are used for BN-600 MOX Fuel Fabrication.
- ❁ Constructional Materials of Standard BN-600 Fuel Elements.
- ❁ MOX Fuel Pellets Fabrication at “MAYAK”.
- ❁ Fuel Element Fabrication at “MAYAK”.
- ❁ Fuel Element Quality Control by “MAYAK” Control Procedures and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

FE design

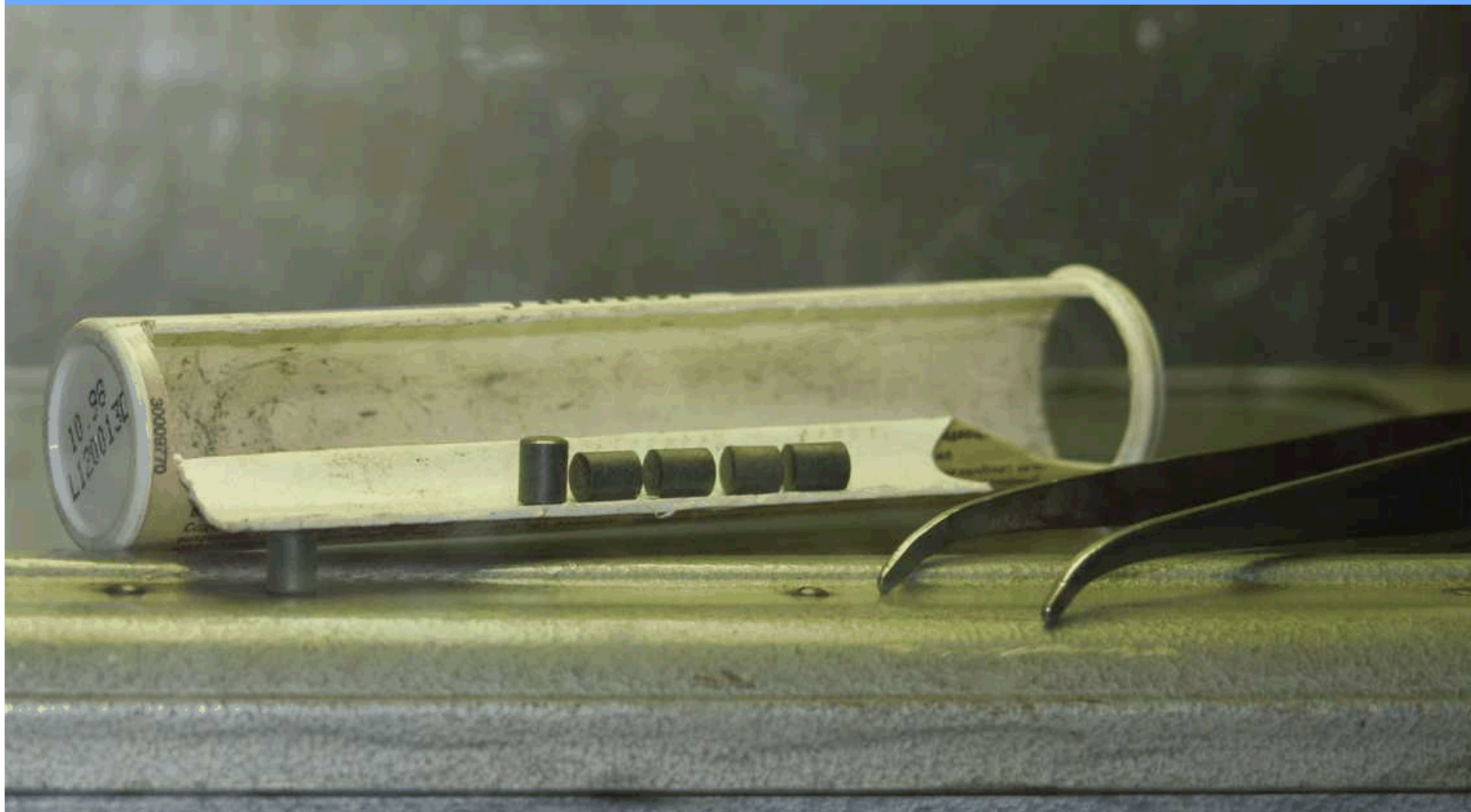


Fuel pellet

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

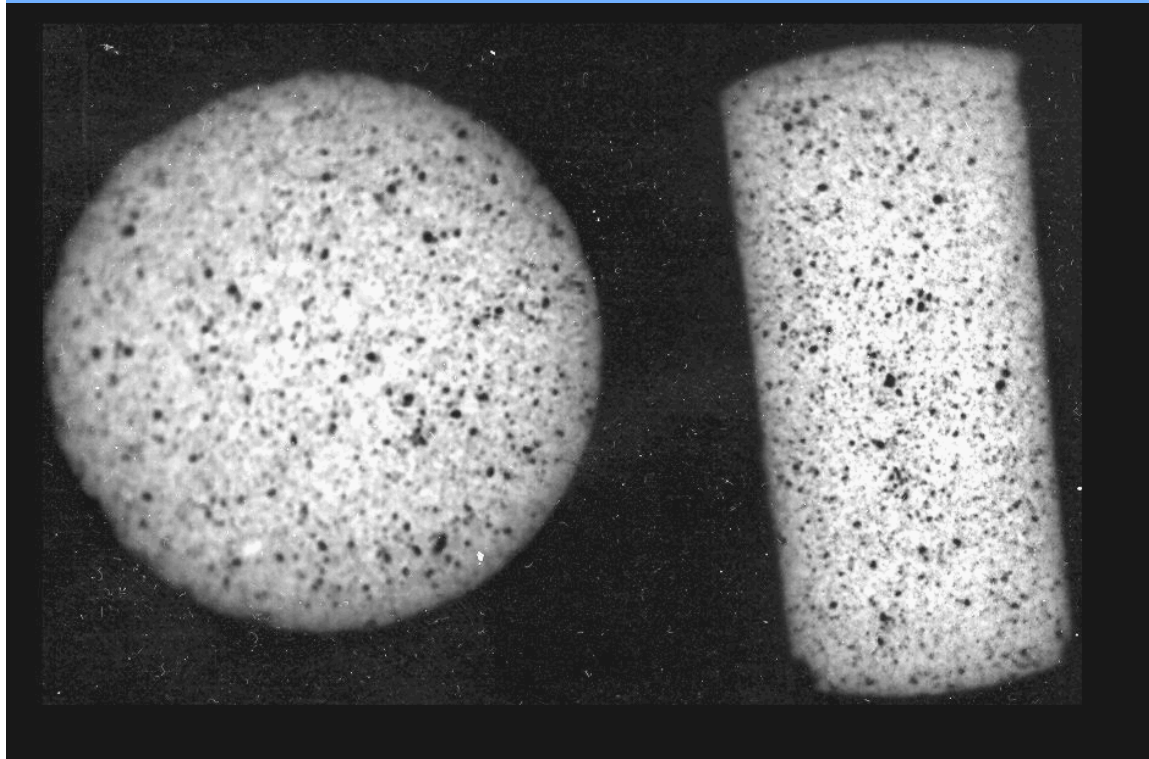


Pellets parameters control



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Pu distribution homogeneity study



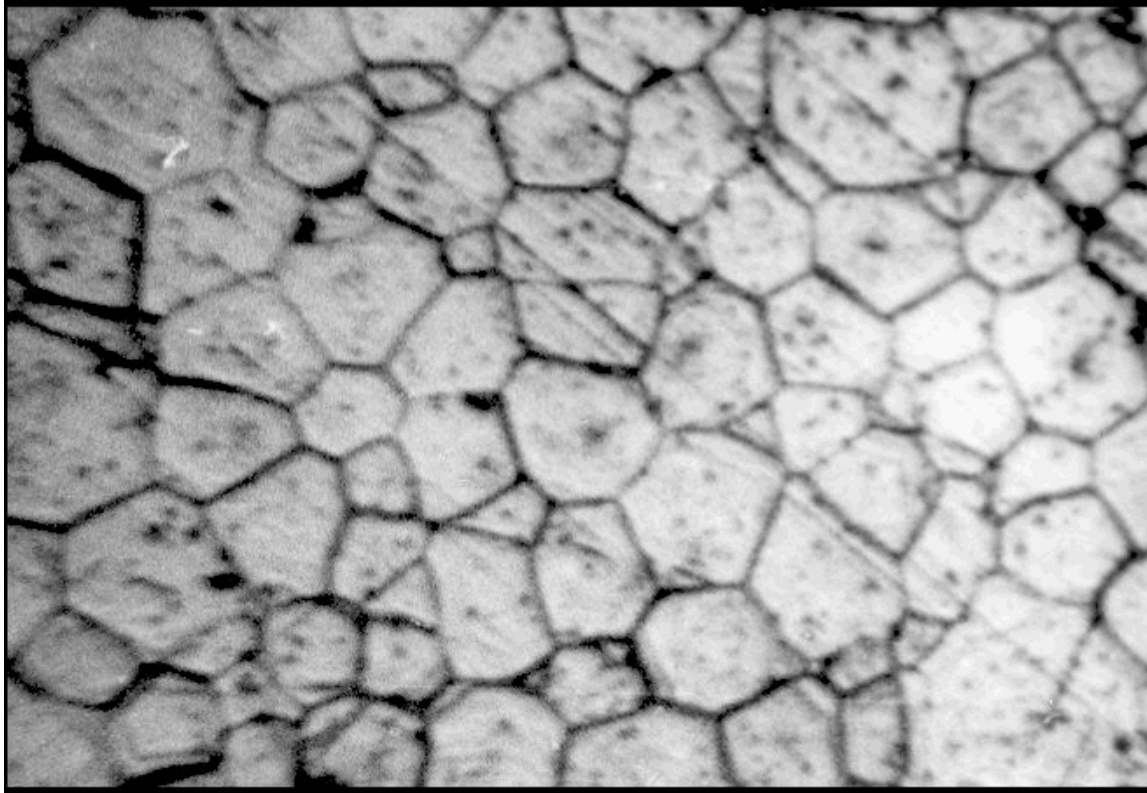
No Pu zones observed here

α -radiography

**Pu zones less
than 100
mkm in
diameter**

**Pu zones area less
than 10% of
microsection area**

Grain and pore dimensions



**Microscopy
study of the
microsections
processed in HNO₃
and HF acids**

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

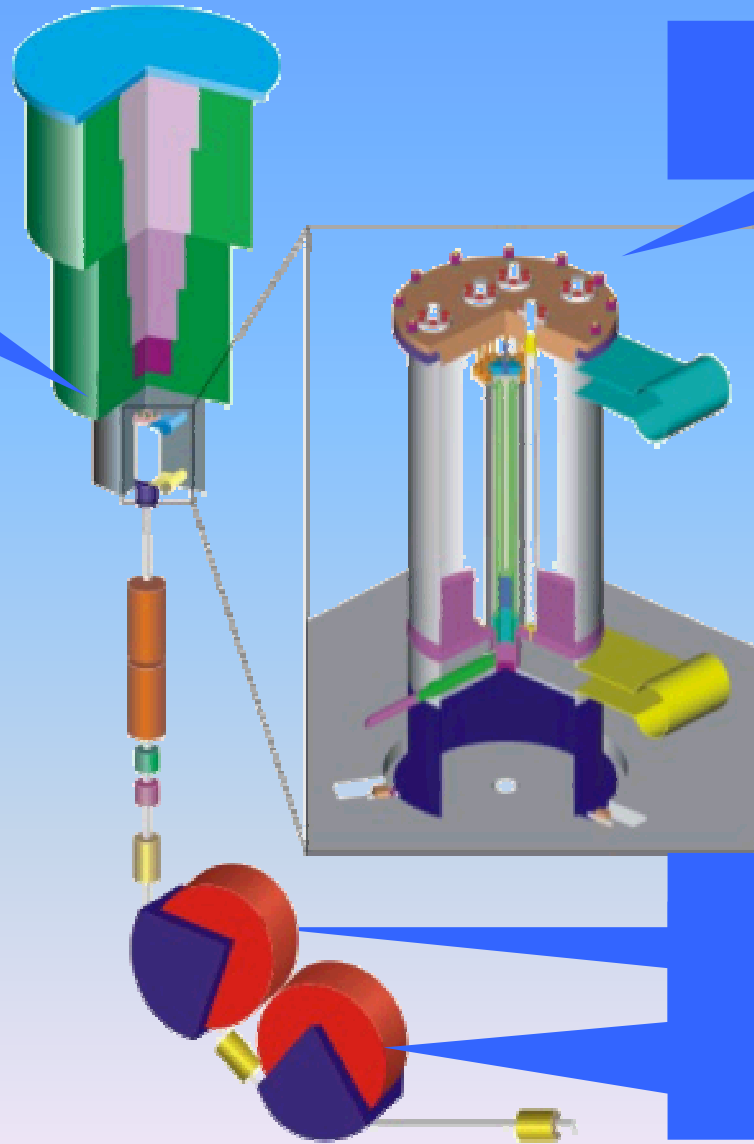
**Grain diameter should be < 50
mkm (20-25 for that sample)**

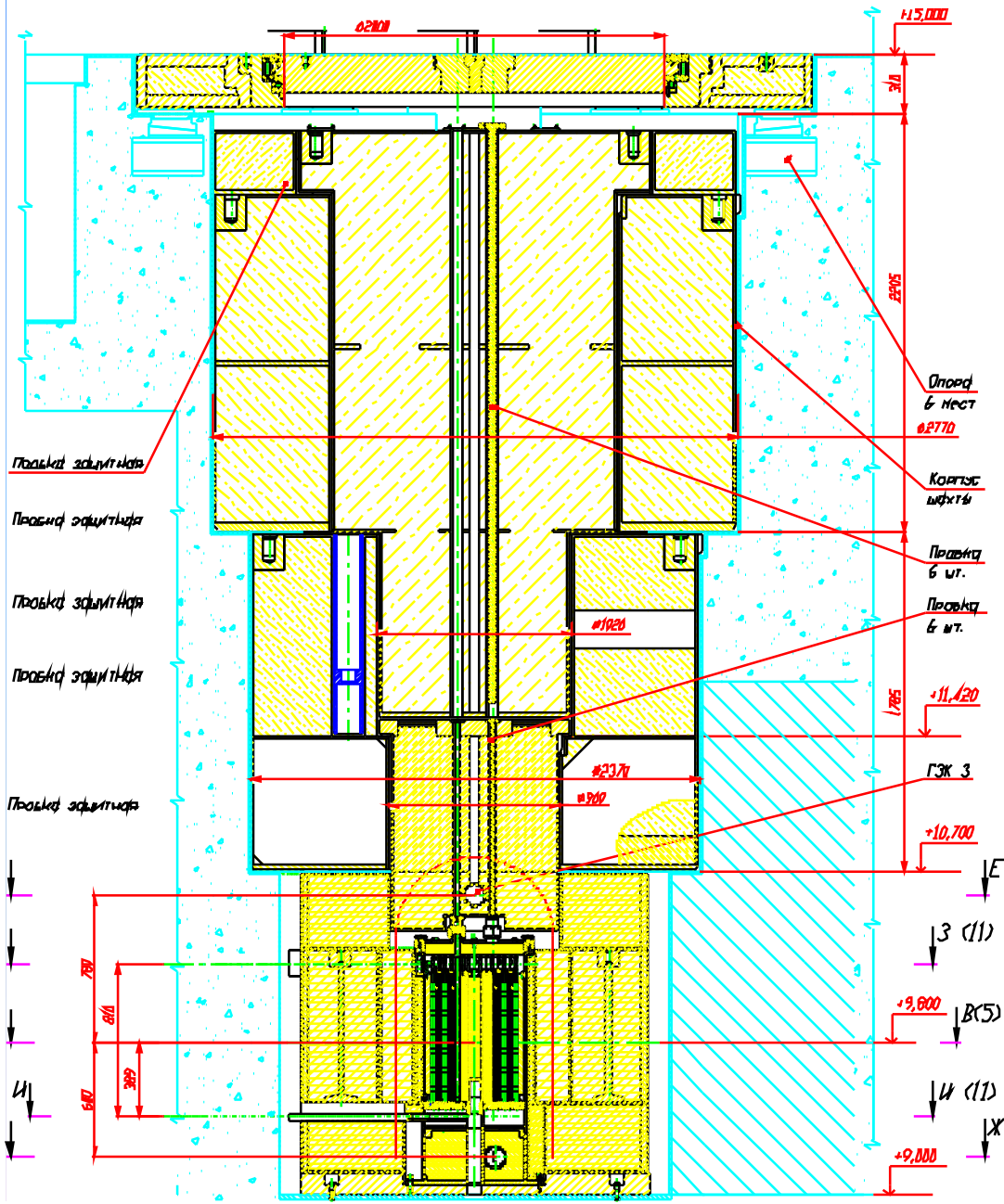
General Layout

Shielding

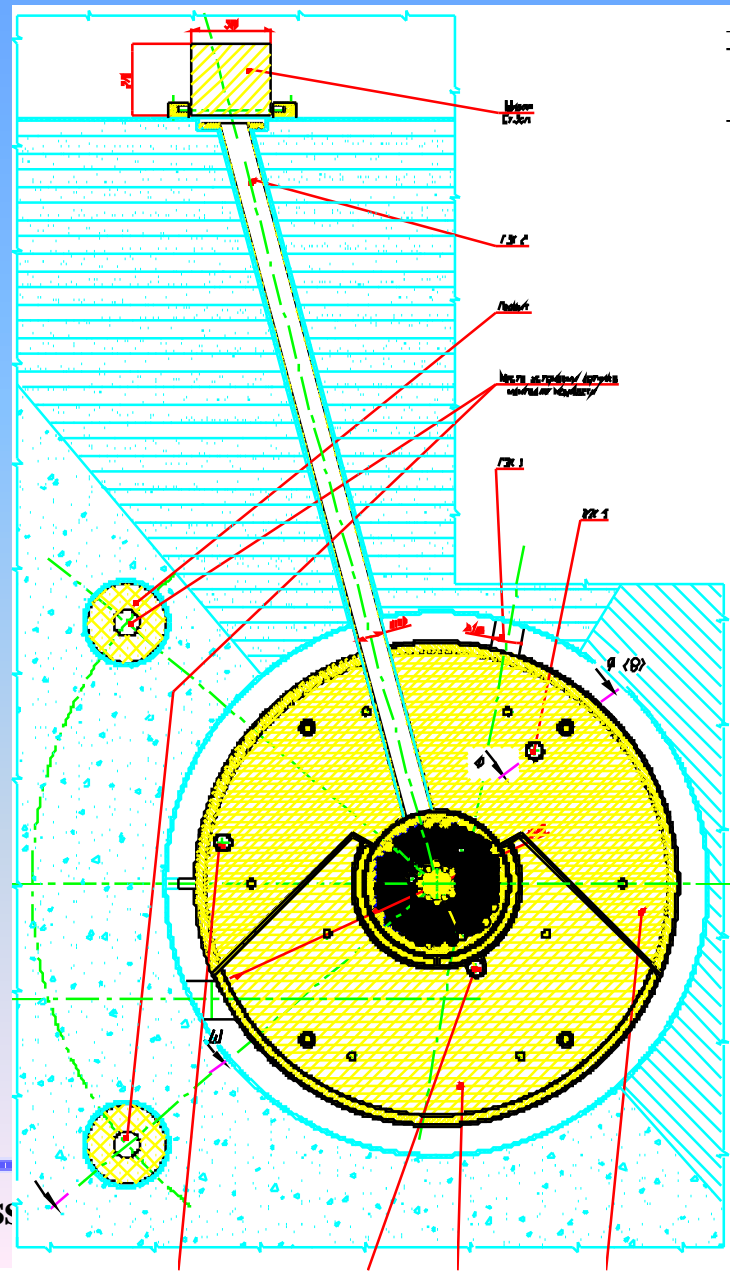
Blanket

Vert.
magnets



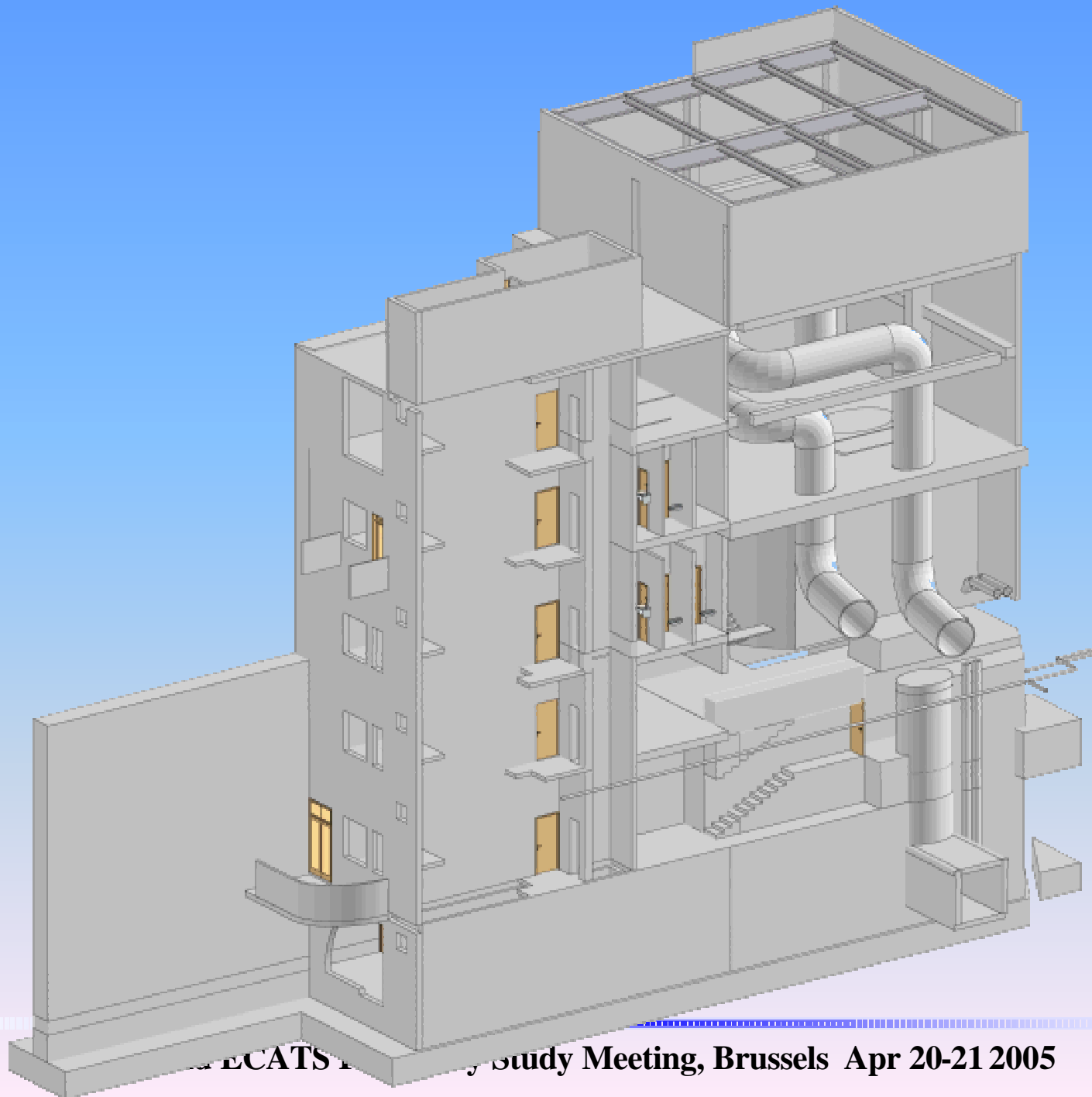


General Layout



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

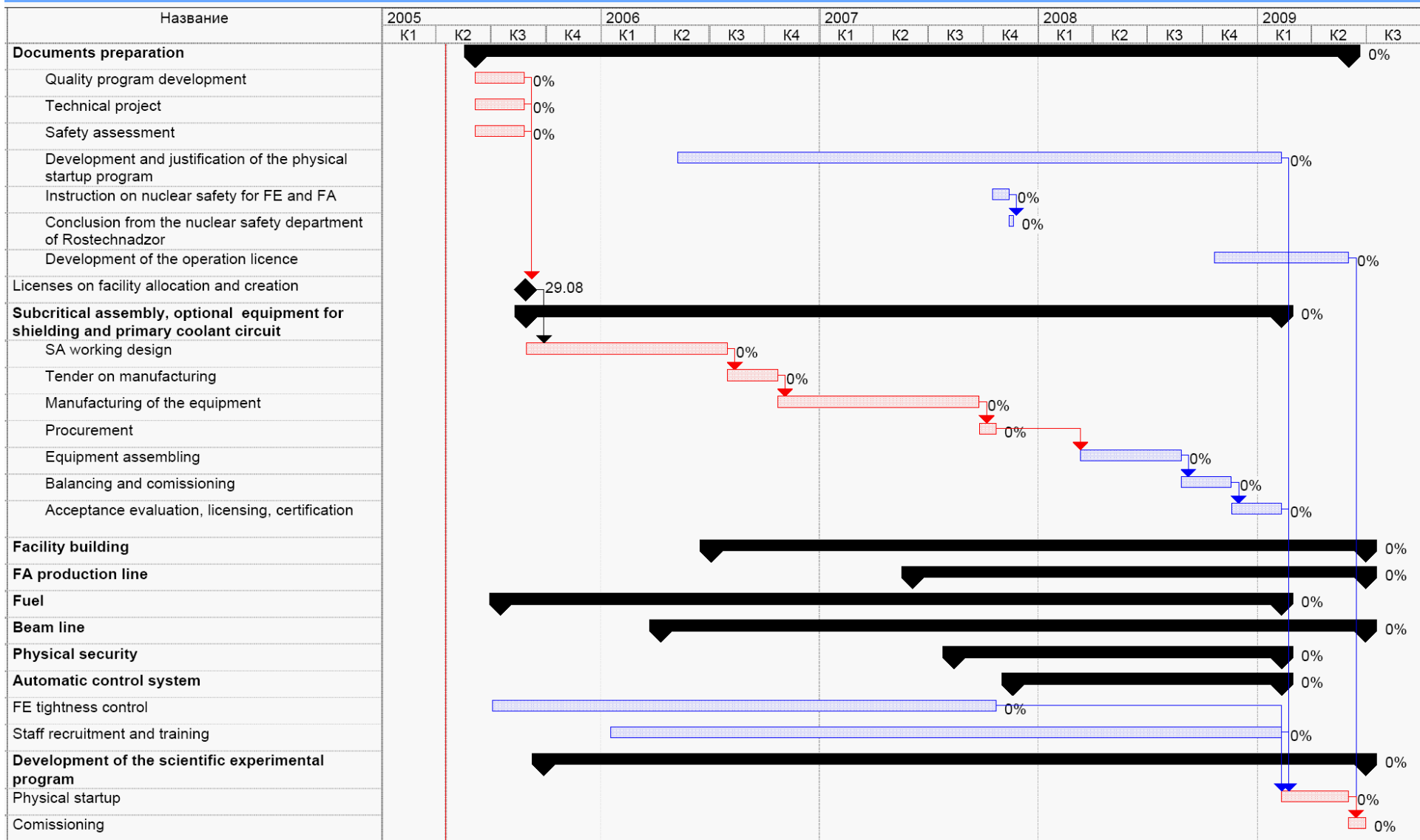


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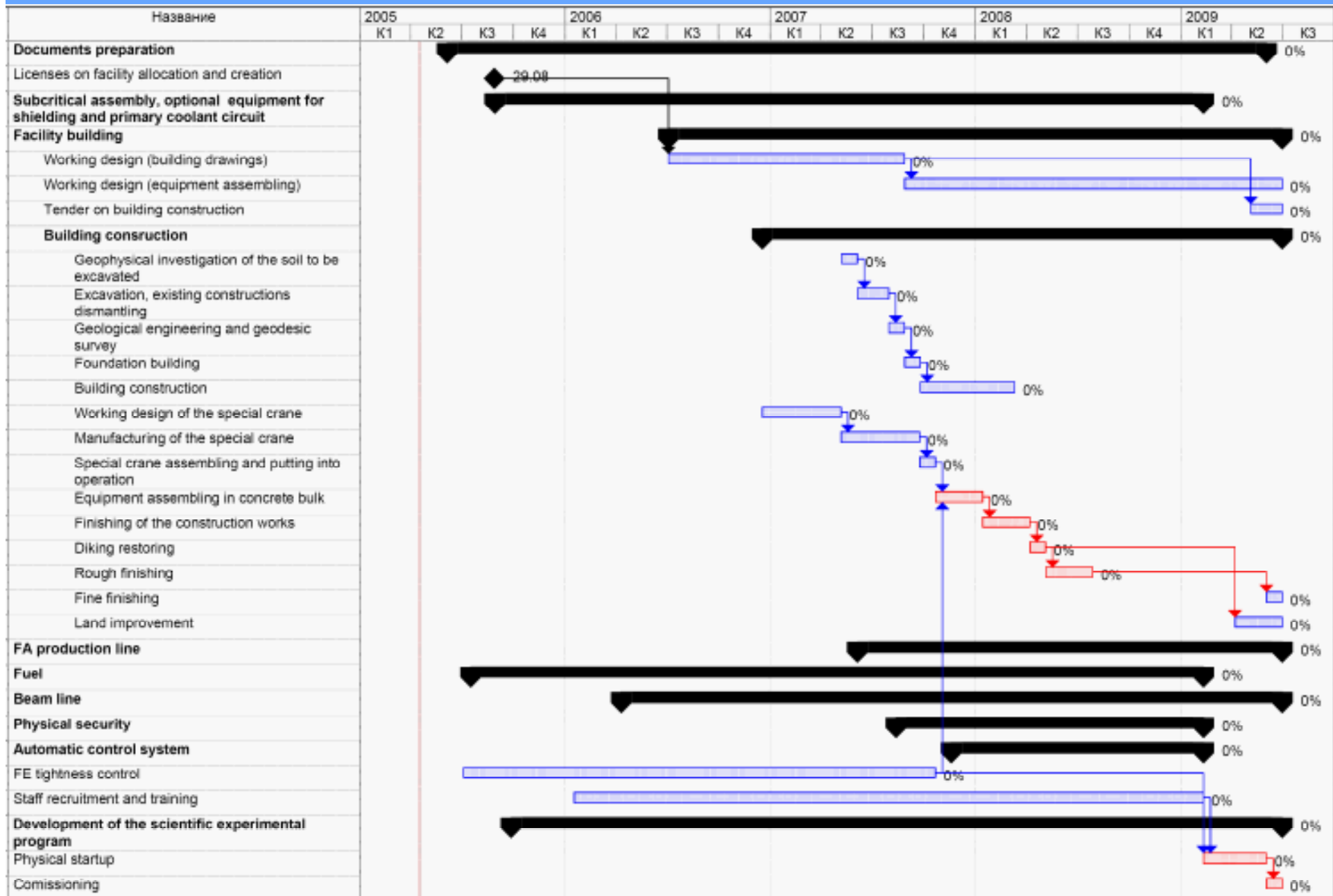
Project Status

- ✿ **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;**

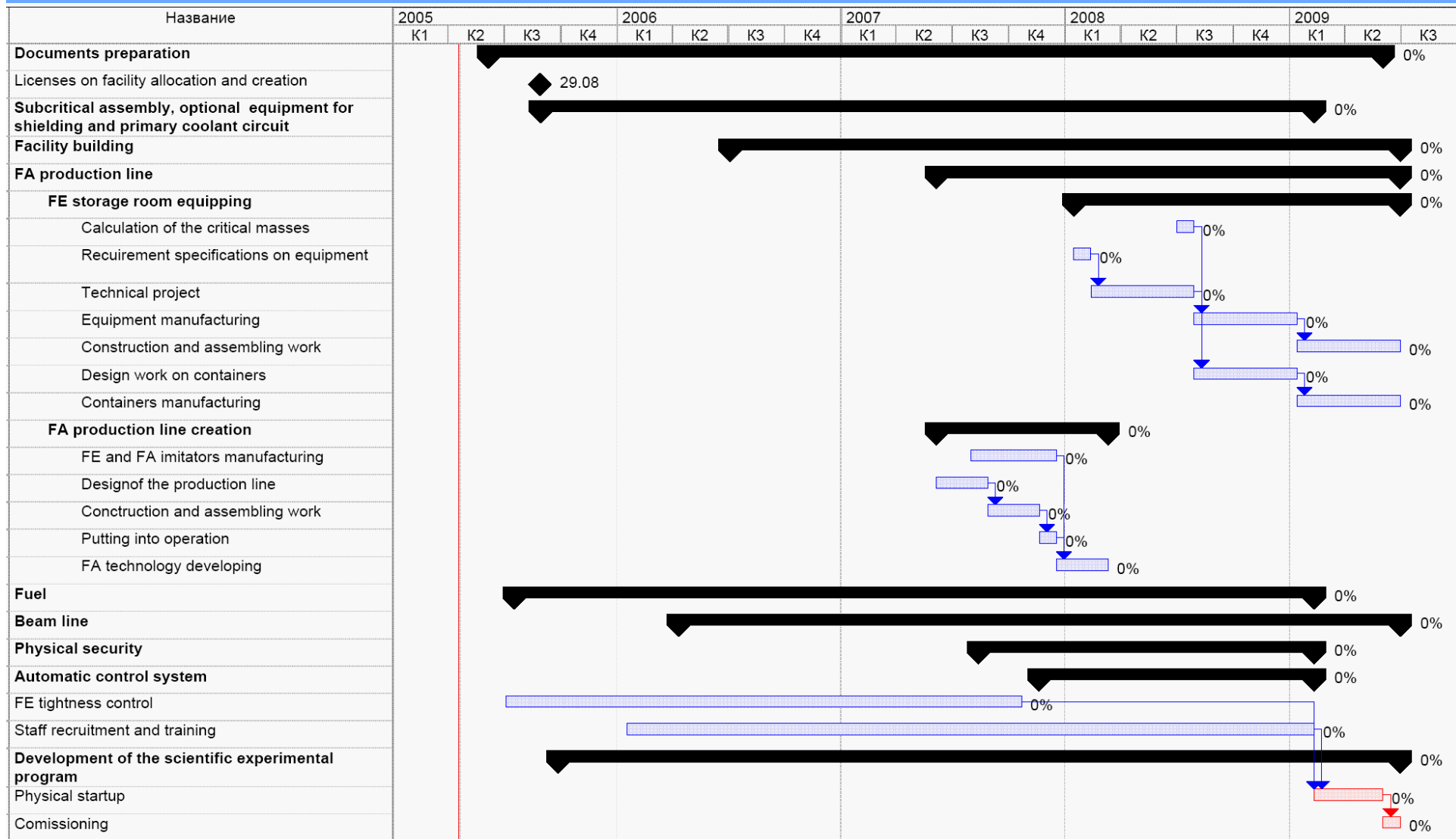
Project Timeline/licensing, blanket/



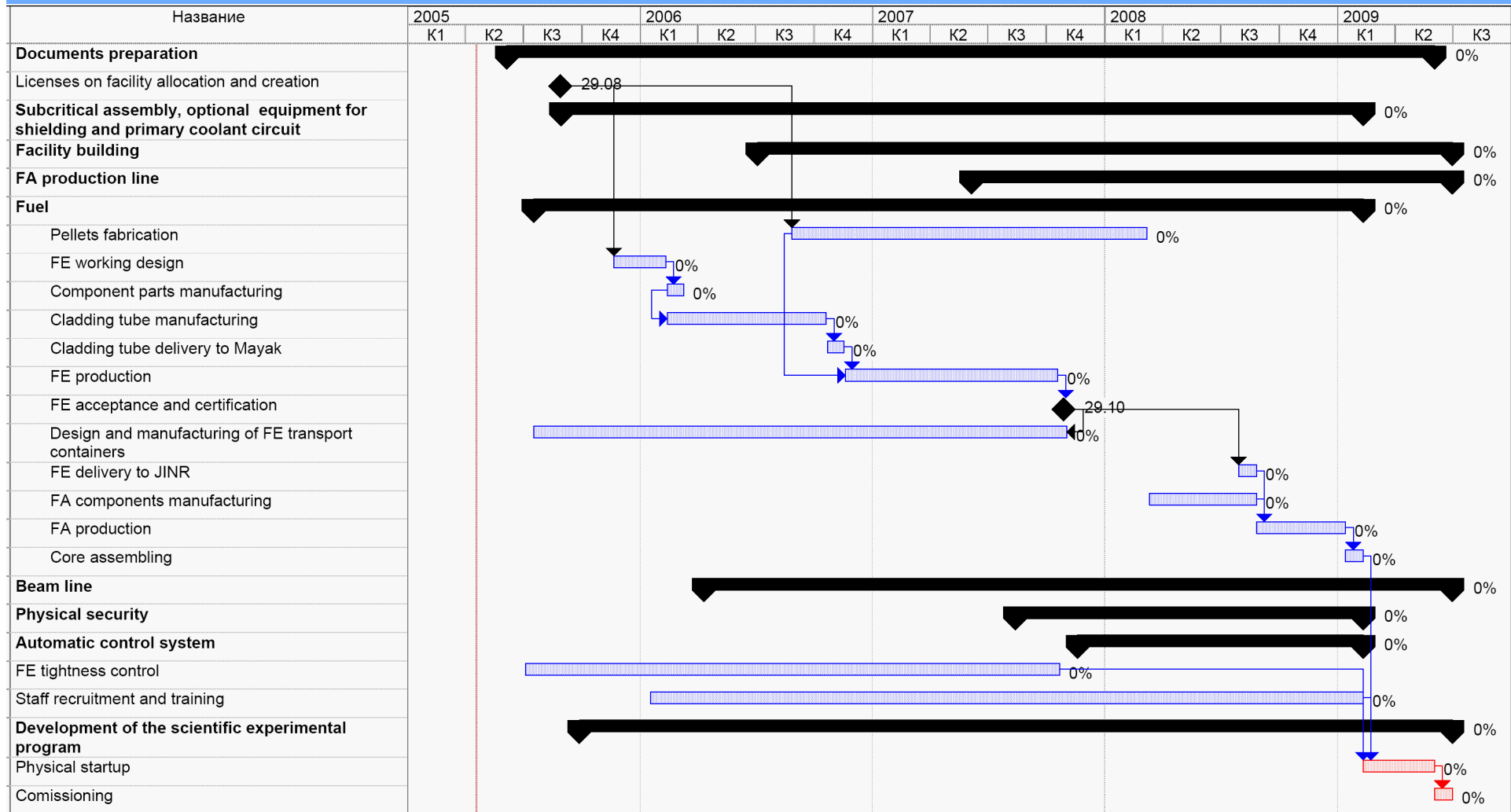
Project Timeline /building/



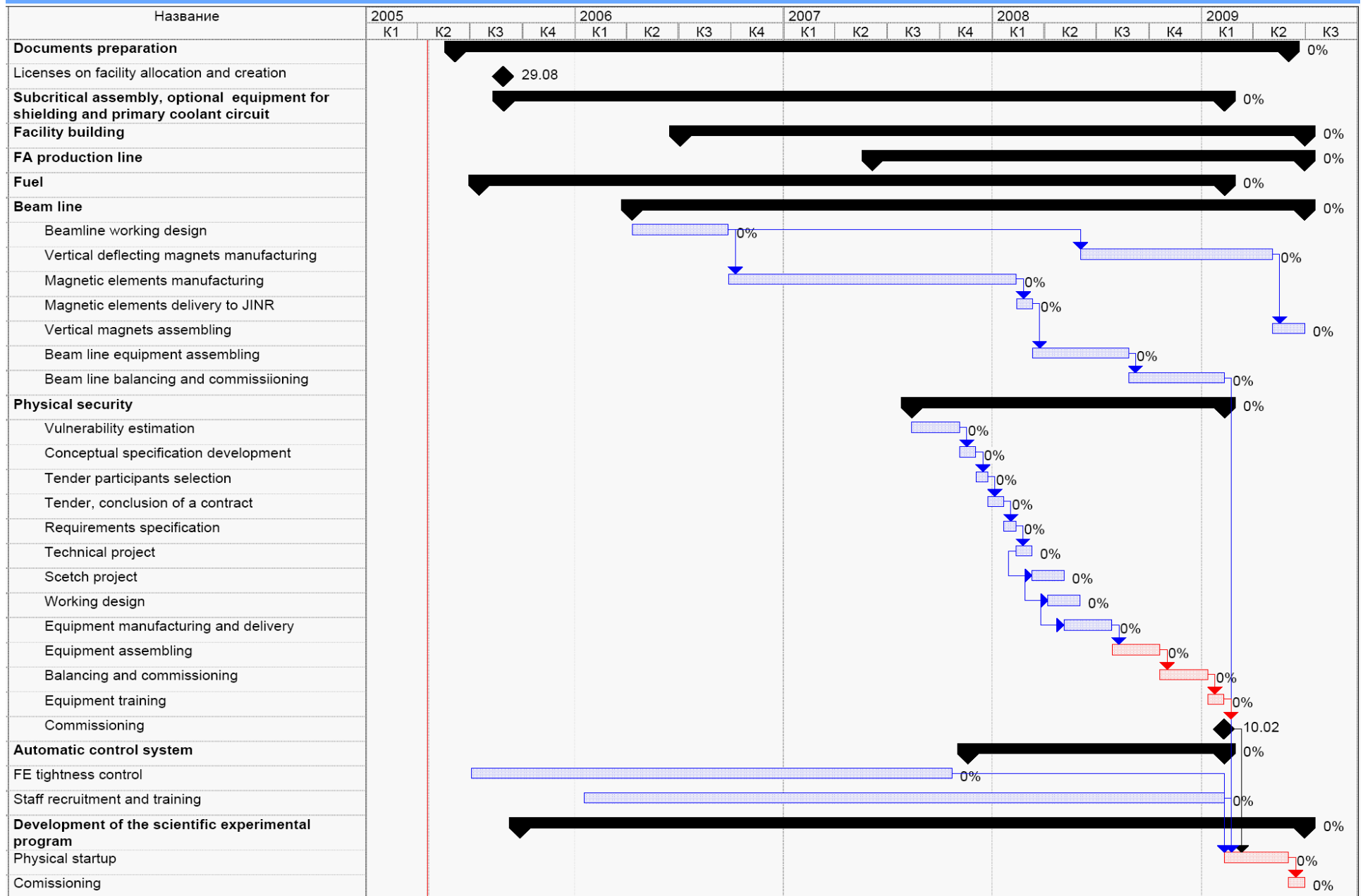
Project Timeline /FA production line/



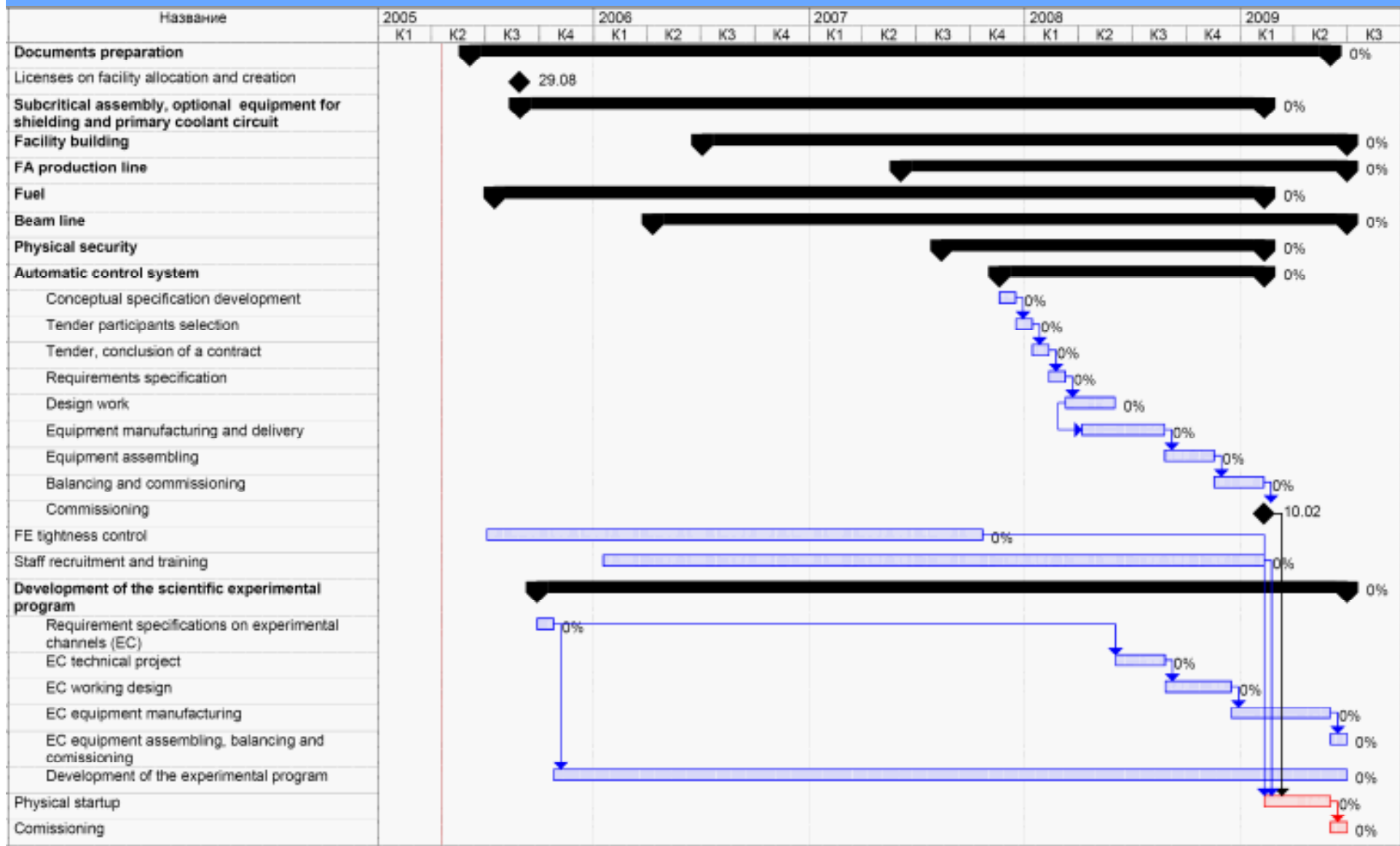
Project Timeline /fuel elements/



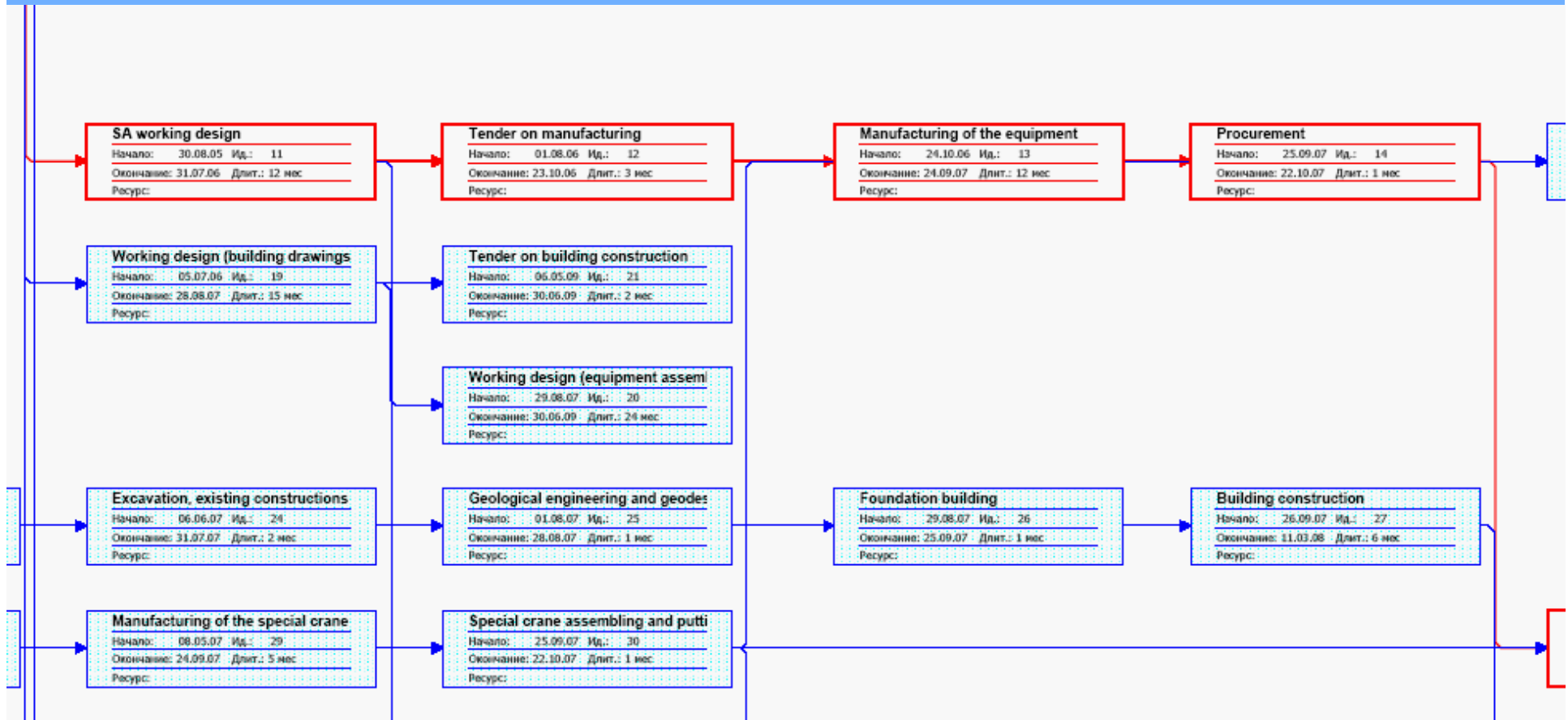
Project Timeline /beam line & phys. sec./



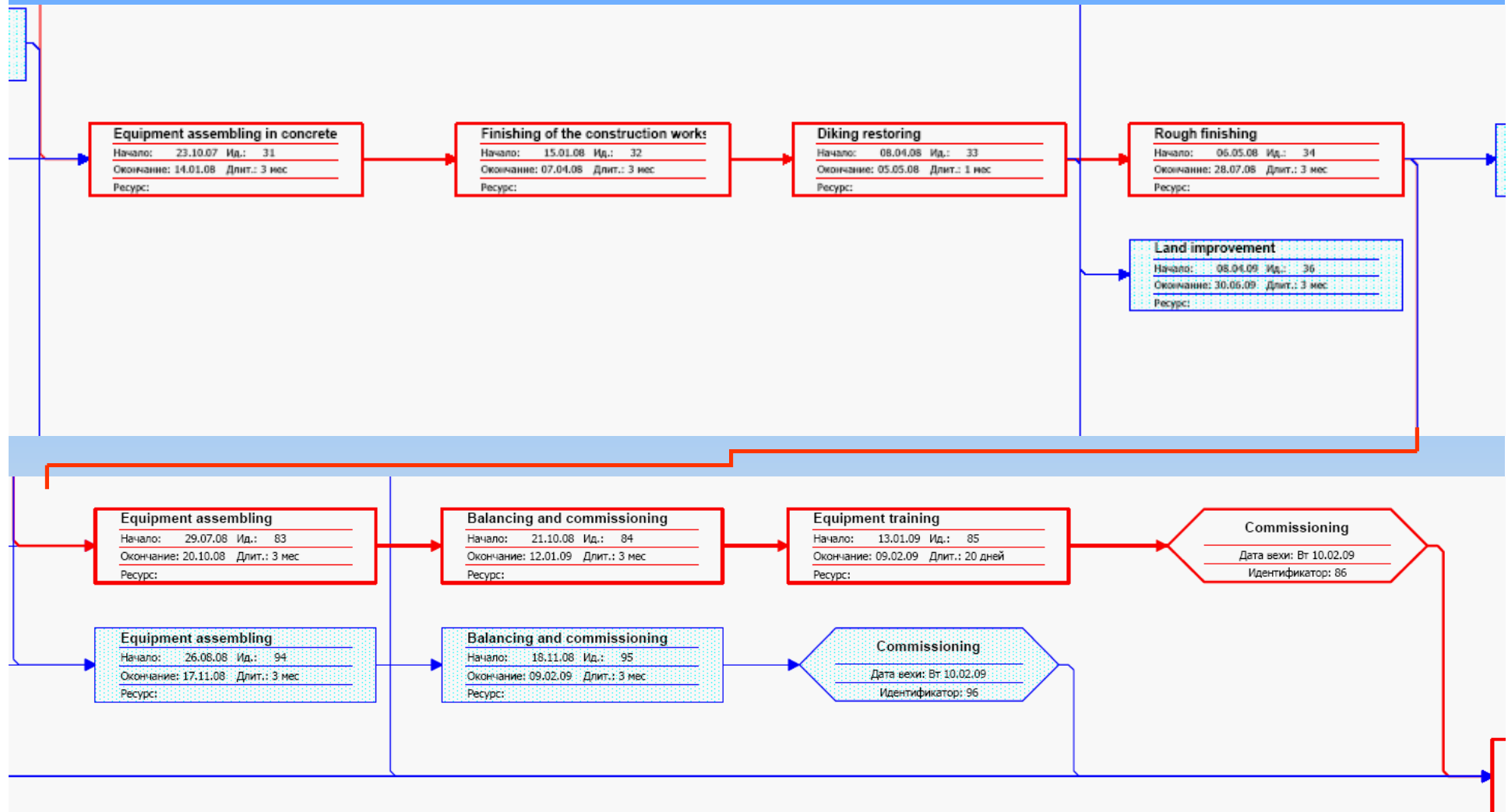
Project Timeline /ACS & exp./



Project Timeline /crit. path: blanket/



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



Cost assessment

Cost in roubles of 2004

- **Blanket & shielding: 92 Mr**
- **Beamline: 24.23 Mr**
- **Construction works: 93.6 Mr**
- **Equipment for fuel storage: 25.32 Mr**
- **Cooling systems: 16.99 Mr**
- **Fuel elements tightness control system: 5.07 Mr**
- **Fuel (3000 FE) 41.82 Mr**
- **Physical security system: 40.63 Mr**
- **Radiation control system: 16.84 Mr**
-
- **TOTAL: 434 Mroubles.....**