Pulsed Neutron Generators at D.V. Efremov Research Institute

- In the last years the interest towards pulse neutron generators is growing due to continuing research in nuclear physics (using flight time methods) and due to the importance of possible applications. Such generators allow developing highly effective detectors for radioactive materials, but as well for explosives, drugs, and poisons.
- The Efremov Institute has carried out a series of research and development projects in order to create generators capable of producing neutron fluxes of high intensity in continuous mode, but also capable of operating in pulse mode with a wide range of pulse frequency and repetition rate.

- **НЕЙТРОННЫЙ ГЕНЕРАТОР НГ-12-2**
- **Напряжение, кВ** **300**
- **Ток пучка ионов, мА,** **10**
- Нестабильность ионного тока, % ±5
- ***Непрерывный пучок в линии пучка 1:***
- Ток пучка ионов, мА 10
- Диаметр пучка, мм 20
- Ток ионов водорода, мА 2
- Диаметр пучка, мм 10
- ***Импульсный микросекундный пучок в линии пучка 1:***
- Пиковый ток в импульсе, мА 5
- Длительность импульса, мксек 10-100
- Частота импульсов, Гц 1,10,100,1000
- Диаметр пучка на токоприемнике, мм ≤15
- ***Импульсный наносекундный пучок в линии пучка 2:***
- Ускоряющее напряжение, кВ 250
- Пиковый ток ионов в импульсе, мА 10
- Ширина импульса, fwhm, нсек 1,5
- Диаметр пучка на токоприемнике, мм 10
- Полная длина импульса, нсек 6
- Частота импульсов, МГц 1,2,4
- Частота импульсов, кГц 1-100

NG-12-2

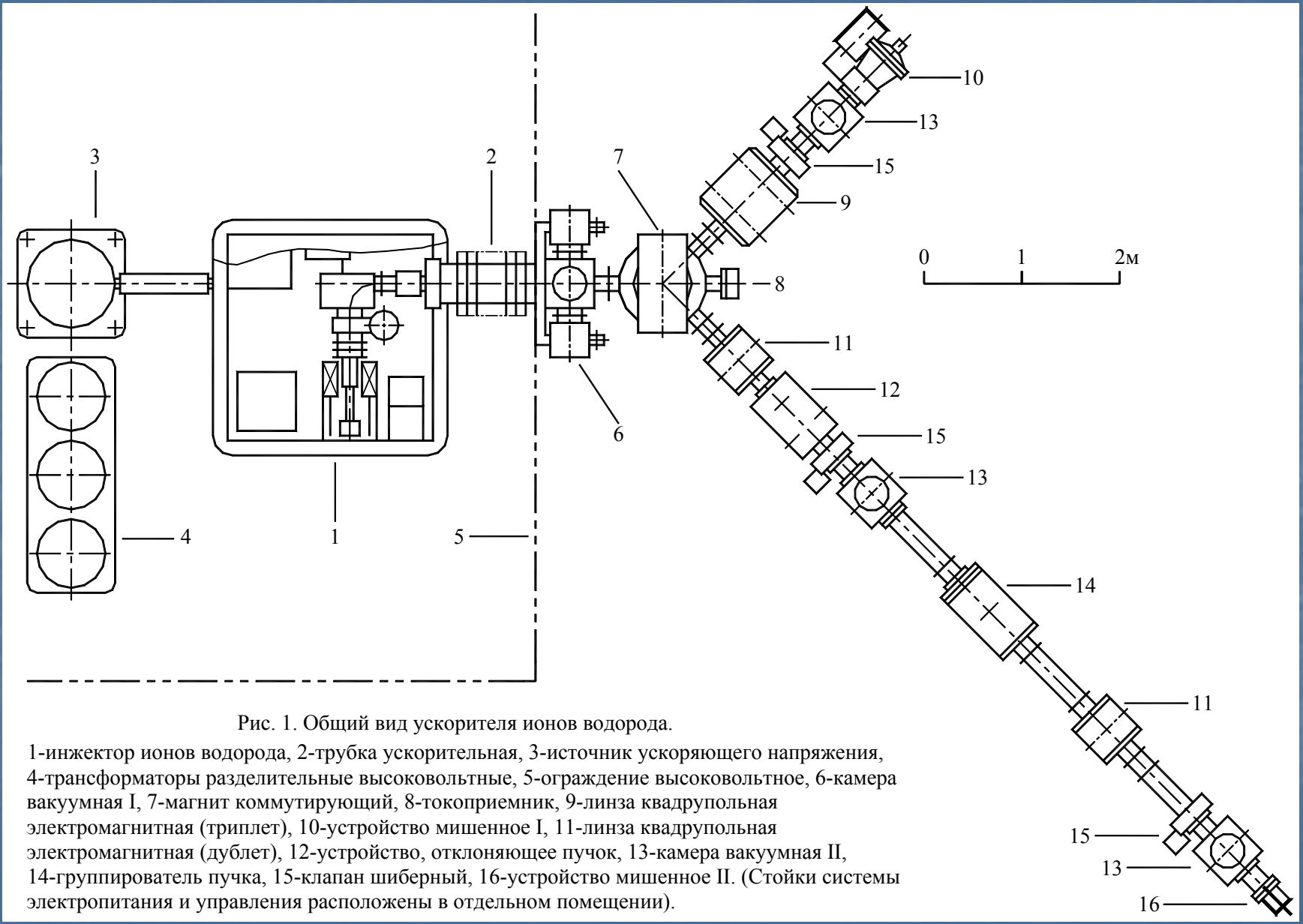
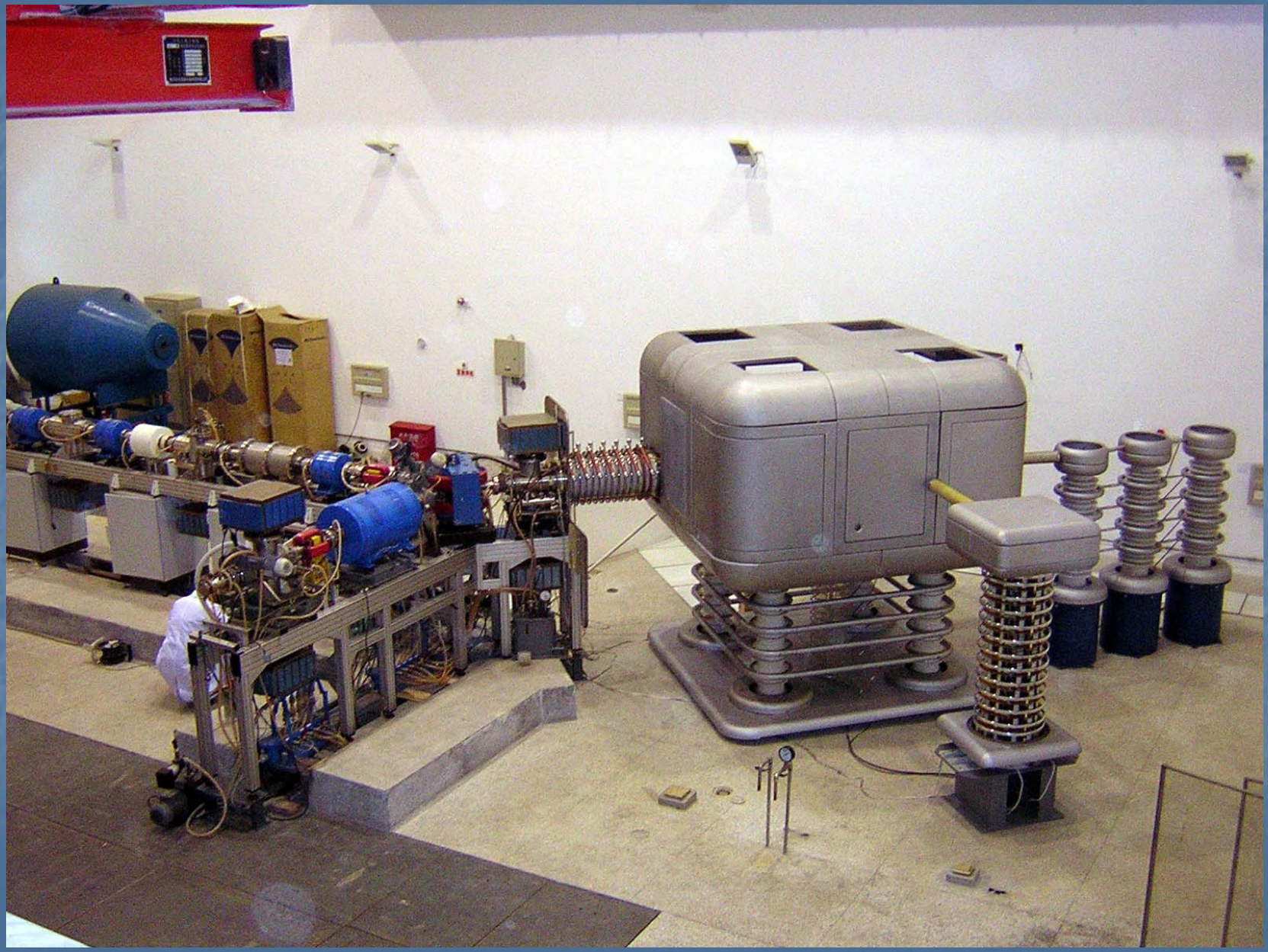


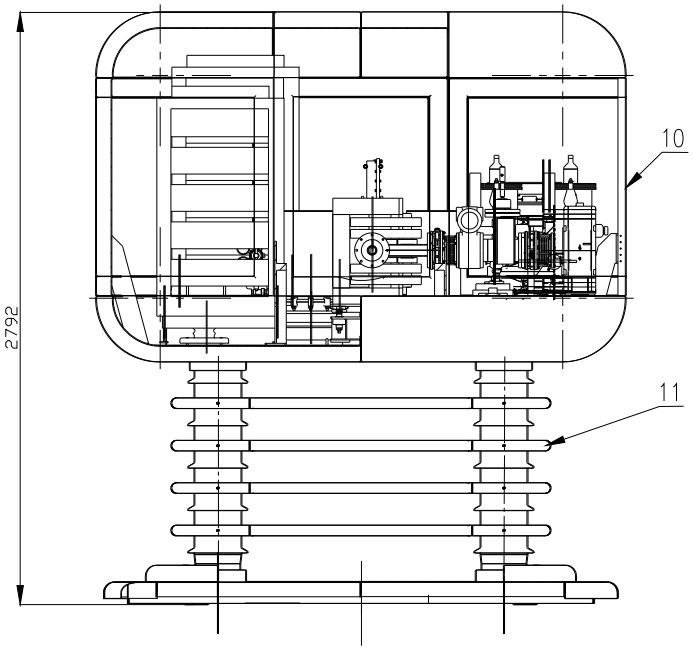
Рис. 1. Общий вид ускорителя ионов водорода.

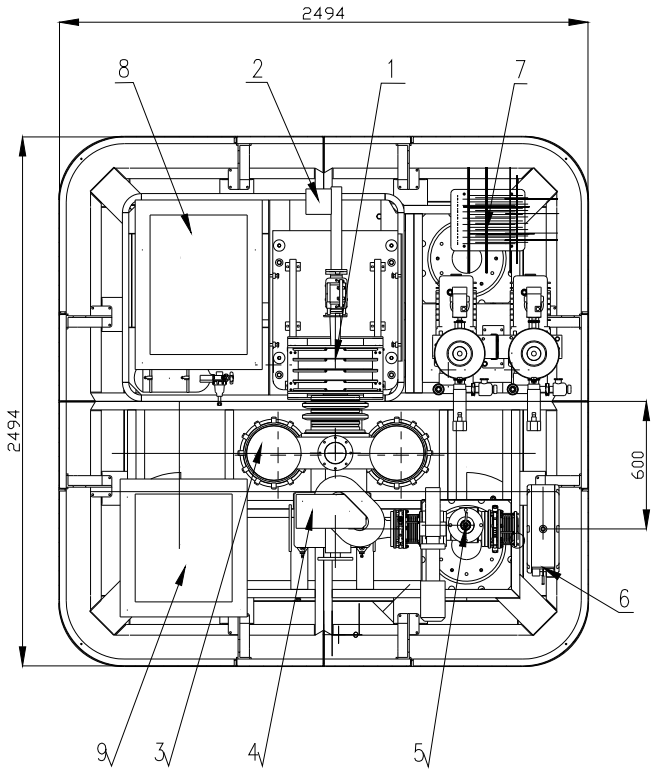
1-инжектор ионов водорода, 2-трубка ускорительная, 3-источник ускоряющего напряжения, 4-трансформаторы разделительные высоковольтные, 5-ограждение высоковольтное, 6-камера вакуумная I, 7-магнит коммутирующий, 8-токоприемник, 9-линза квадрупольная электромагнитная (триплет), 10-устройство мишенное I, 11-линза квадрупольная электромагнитная (дублет), 12-устройство, отклоняющее пучок, 13-камера вакуумная II, 14-группирователь пучка, 15-клапан шиберный, 16-устройство мишенное II. (Стойки системы электропитания и управления расположены в отдельном помещении).

NG-12-2



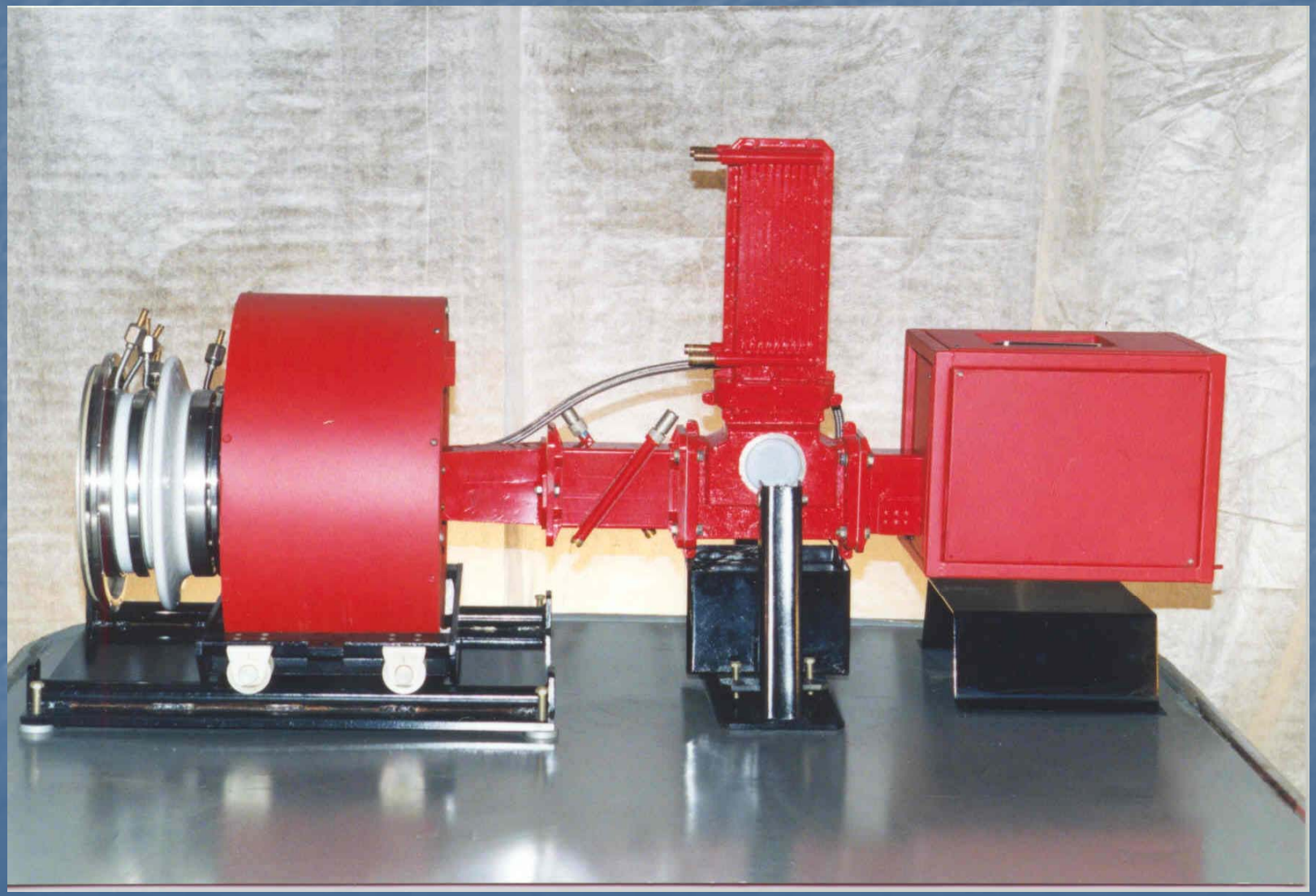
- The neutron generator NG-12-2 is a high-voltage accelerator for deuterium ions with an acceleration voltage 300 kV and a beam current of deuterium atomic ions up to 15 mA.
- The ion injector is installed in the high-voltage terminal of the accelerator. It includes an ion source with initial beam forming system, an analyzing 90-degree electromagnet, an autonomous vacuum system and electric power supply and control system.
- The ion source is an ECR one with a four-electrode ion beam formation system. Spatial and angular characteristics of the beam at the accelerating tube input are controlled with the analyzing electromagnet with double focusing and a solenoid lens.





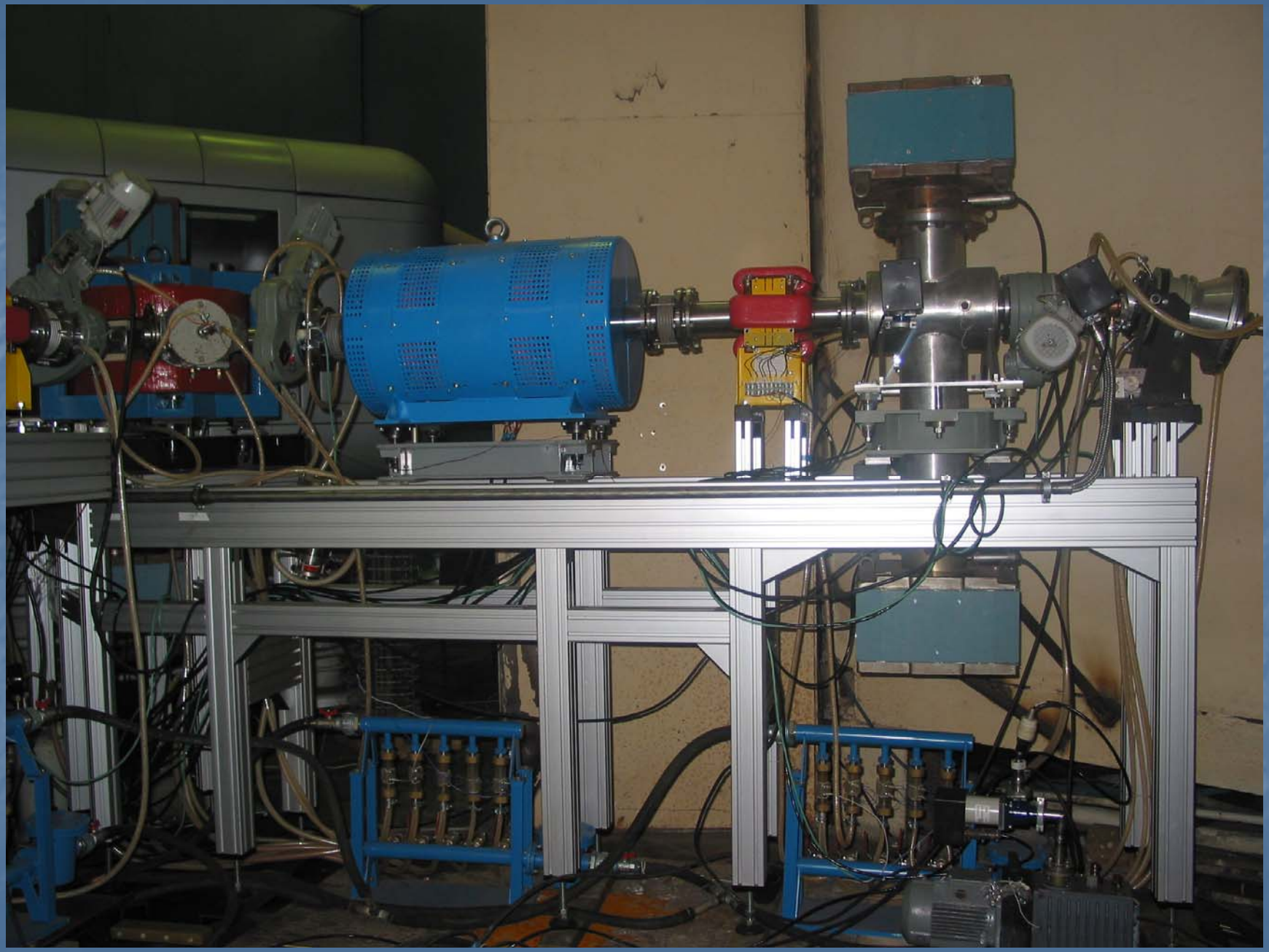
1– Источник ионов водорода
2– Магнетрон
3– Камера вакуумная
4– Электромагнит (90, R=200мм)
5– Измеритель тока пучка подвижный
6– Линза соленоидальная (d=100мм)
7– Источник ускоряющего напряжения
8– Система электропитания источника ионов
9– Система электропитания инжектора ионов
10– Электрод высоковольтный
11– Опора изоляционная

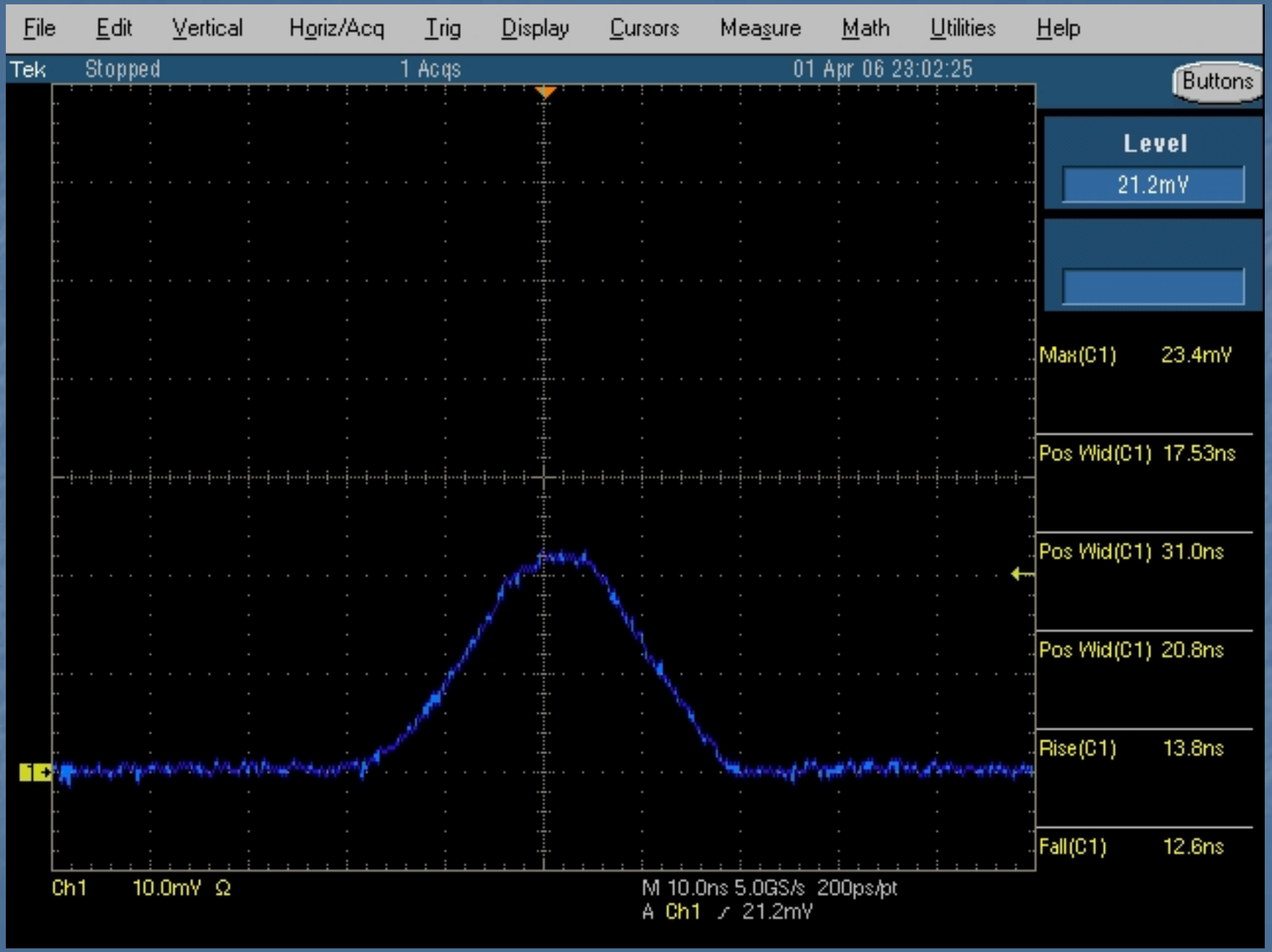
ECR-ion source



- The ion optical system of the accelerator has been designed in order to obtain the deuterium ion beam current of up to 20 mA at the accelerator output, in the plane of the distribution magnet.
- This beam has an emittance and regular divergence values required for further transport towards the beam.
- The 45-degrees electromagnet allows switching the beam between the two transport channels.

- The first channel is designed to operate in continuous and microsecond pulse modes. An ion beam with pulse duration of 10-100 ms and repetition rate up to several kHz is obtained by microwave discharge modulation in the ion source.
- The second channel is designed for obtaining ion pulses of 1-2 ns duration at the stationary beam. Such pulses are obtained by means of a beam chopper and a clystron buncher.

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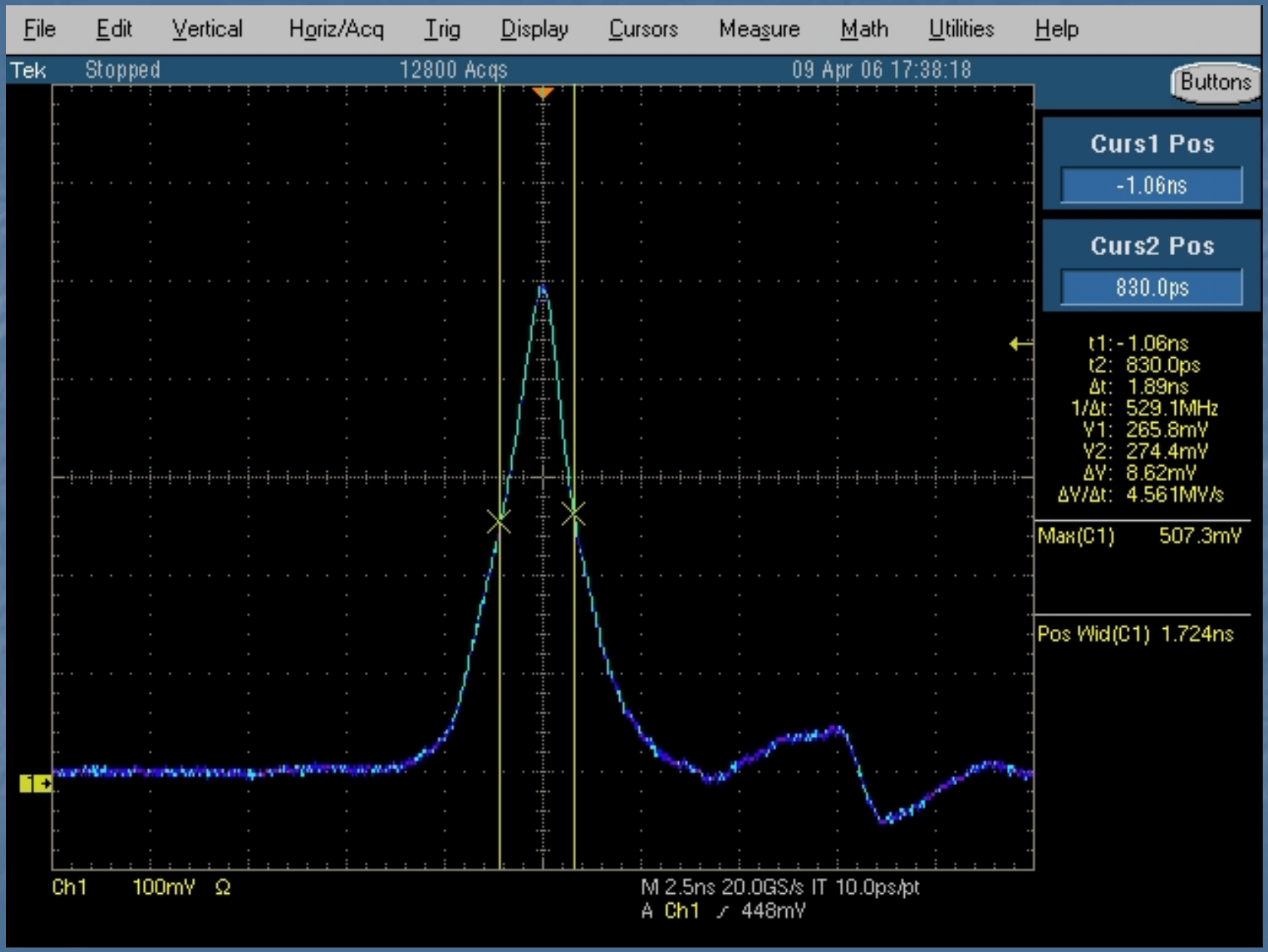
Buttons
Level
21.2mV
Max(C1) 23.4mV
Pos Wid(C1) 17.53ns
Pos Wid(C1) 31.0ns
Pos Wid(C1) 20.8ns
Rise(C1) 13.8ns
Fall(C1) 12.6ns
Ch1 10.0mV Ω
M 10.0ns 5.0GS/s 200ps/pt
A Ch1 ⟋ 21.2mV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Tek Stopped 12800 Acqs 09 Apr 06 17:38:18
Buttons
Curs1 Pos
-1.06ns
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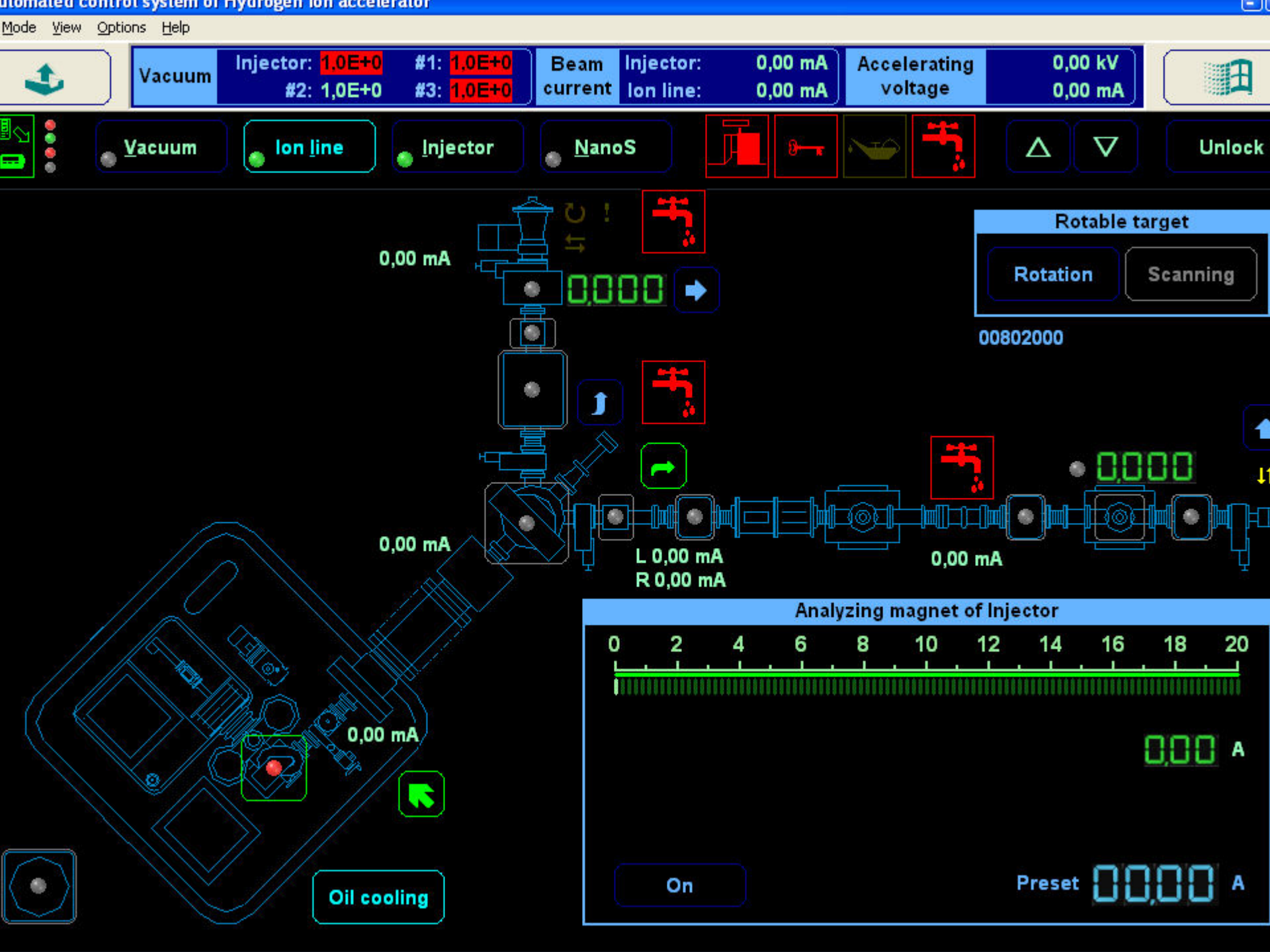
830.0ps
t1: -1.06ns
t2: 830.0ps
Δt: 1.89ns
1/Δt: 529.1MHz
V1: 265.8mV
V2: 274.4mV
ΔV: 8.62mV
ΔV/Δt: 4.561MV/s
Max(C1) 507.3mV
Pos Wid(C1) 1.724ns
Ch1 100mV Ω
M 2.5ns 20.0GS/s IT 10.0ps/pt
A Ch1 ⟋ 448mV

- The neutron generator allows obtaining the beam current of atomic deuterium ions of 15 mA at the rotating target of 230 mm diameter, with the beam diameter of 20 mm. For the pulsed mode with pulse duration 10-100 ms current amplitude can be up to 20 mA.
- The second channel allows obtaining peak current up to 10 mA with pulse duration 1.7 ns. The repetition rate can be set to 1, 2, and 4 MHz, or it can be varied smoothly between 1-100 kHz.
- The generators like NG-12-2 can operate in large research centers, but there is also a demand of less expensive generators with lower neutron yield, but with auxiliary systems broadening the range of possible applications.


Automated control system of Hydrogen ion accelerator
Mode View Options Help
Vacuum
Injector: 1,0E+0 #1: 1,0E+0
#2: 1,0E+0 #3: 1,0E+0
Beam current
Injector: 0,00 mA
Ion line: 0,00 mA
Accelerating voltage
0,00 kV
0,00 mA
Vacuum
Ion line
Injector
NanoS
Unlock
0,00 mA
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Rotable target
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Scanning
00802000
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L 0,00 mA
R 0,00 mA
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Analyzing magnet of Injector
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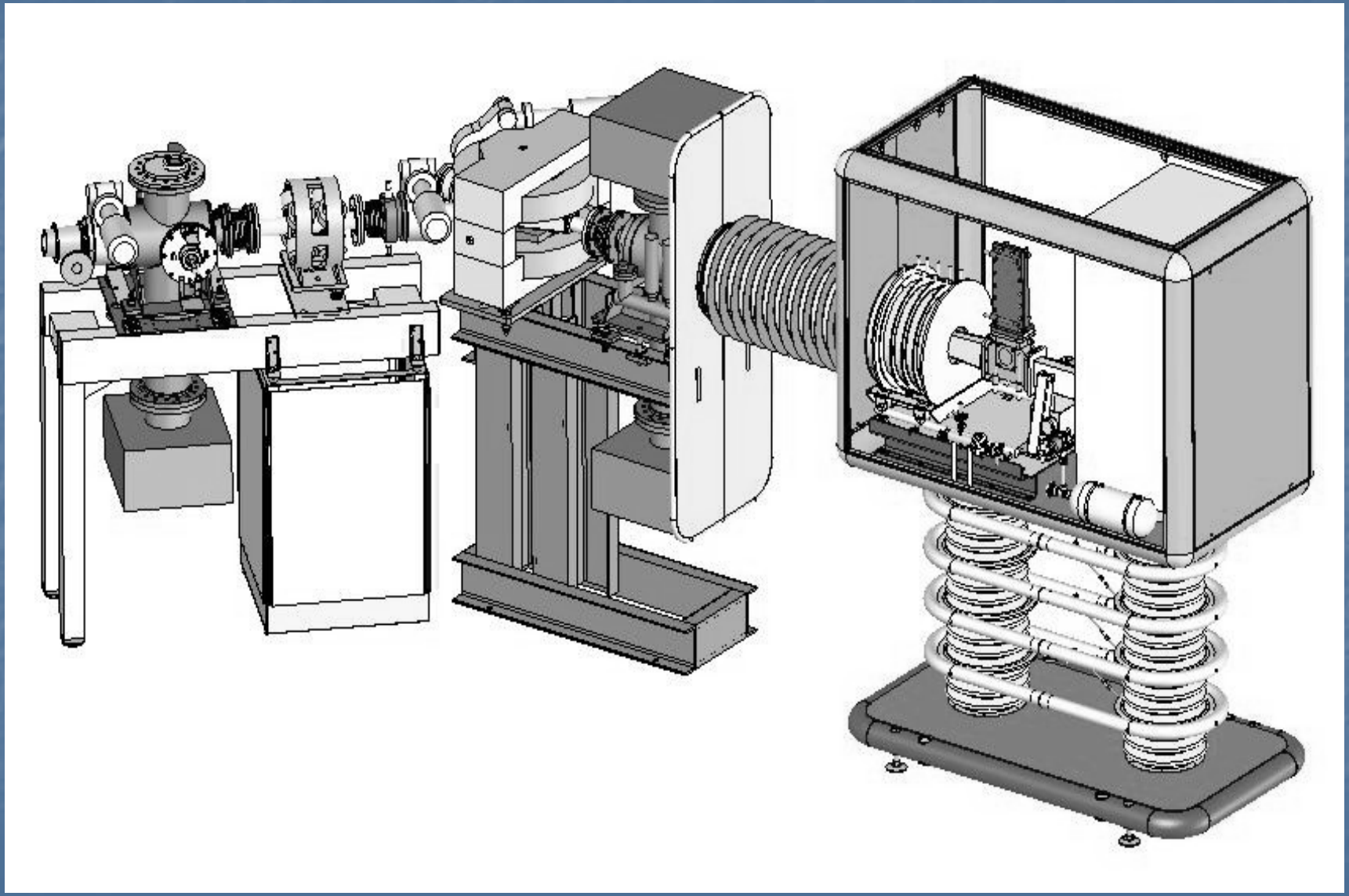
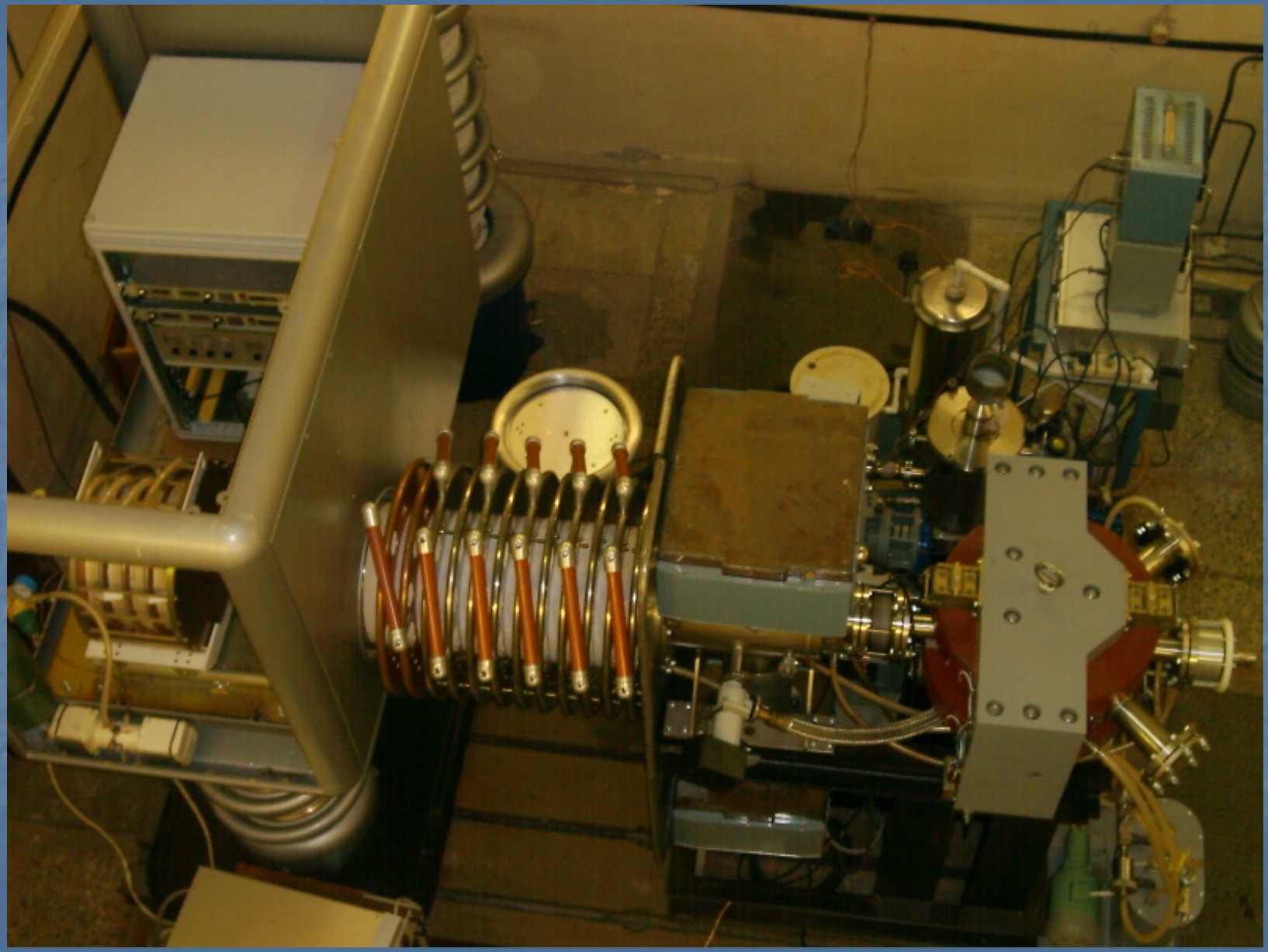
0,00 A
On
Preset 00,00 A
Oil cooling

NG-11-I



NG-11-I



- Основные технические характеристики генератора:
- Ток пучка атомарных ионов дейтерия на мишени, мА ... 5
- Ускоряющее напряжение, кВ 175
- Диаметр пучка на мишени, мм ..... 5÷10
- Выход (Д-Т) нейтронов, н/с 5x1011
- Длительность импульса (fwhm), с .....(2 -10)10-9
- Частота повторения, с-1.....105-106
- Средний выход (Д-Т) нейтронов при частоте повторения 106 с-1 , нейтр/с(1-5)x109

NG-11-I

- A neutron generator NG-11I is designed to obtain a neutron yield of 5x1011 n/s in continuous mode. It is supplied with a microsecond pulse generation system which operates by modulation of the ion source microwave discharge.
- The generator consists of an accelerator of deuterium ions with acceleration voltage of 180 kV and atomic ion beam current at the target up to 5 mA.

Pulsed Neutron Generators at D.V. Efremov Research Institute

	Sneg-13	NG-12-2	NG-11-I
High voltage, kV	250-300	250-300	180-200
Ion beam current, mA	100	15	5
Ion beam diameter, mm	40	20	5
Neutron flux, n/s	$1x10^{13}$	$2x10^{12}$	$5x10^{11}$
Pulse, μs	10-100	10-100	1-100
Pulse, ns		1-3	2-10