ROSATOM State Atomic Energy Corporation

STC «Linear accelerators and cyclotrons»

«Experience on the Application of Automated Control Systems for Cyclotrons with Different Energies of Accelerated Particles»

Speaker: head of laboratory Kuzhlev A.N.

Joint Stock Company
"D.V. Efremov Institute of Electrophysical Apparatus"
(JSC "NIIEFA")
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Classical cyclotrons of NIIEFA

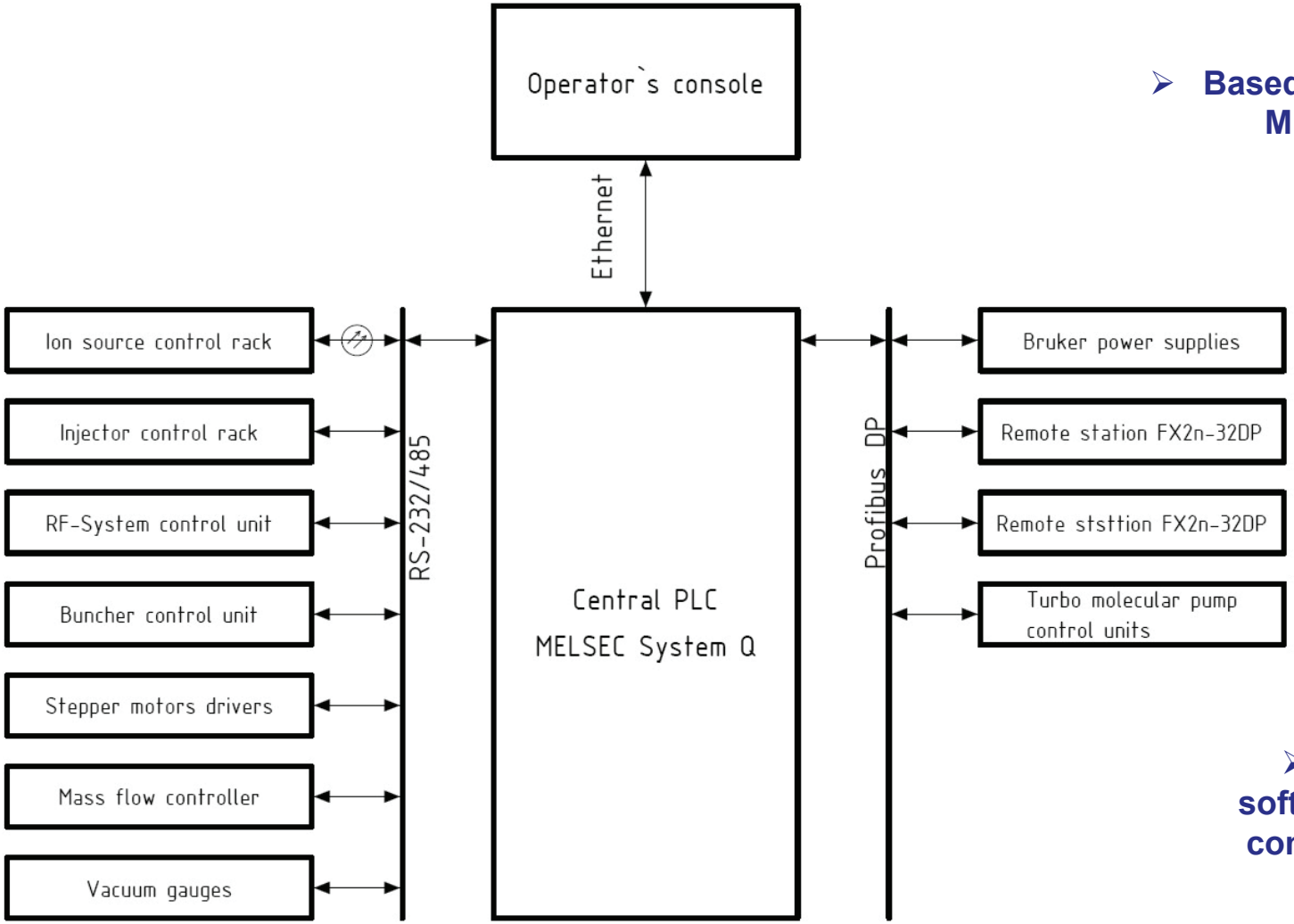
- More than 70-year history of NIIEFA
- More than 35 types of cyclotrons

Type of cyclotron	The energy and type of accelerated ions	Diameter of poles of electromagnet	Location and year of commissioning
M-S	14 MeV, D 7 MeV, H 28 MeV, He-4(+2)	150 cm	Moscow 1947
R-7	14 MeV, D 28 MeV, He-4 (+2)	120 cm	Moscow, Tomsk, Sverdlovsk, Kiev 1955-1958
U-120	14 MeV, D 10 MeV, H 28 MeV, He-4(+2)	120 cm	Leningrad, Dubna, Beijing, Bucharest, Prague, Dresden, Cracow 1958-1962
U-150	22 MeV, H 22 MeV, D 44 MeV, He-4(+2)	150 cm	Obninsk, Dubna, Alma-Ata, Tashkent, Lanzhou 1960-1964
U-300	K=250 MeV Heavy ions	310 cm	Dubna 1962

Isochronous cyclotrons NIIEFA

Type of cyclotron	The energy and type of accelerated ions	Diameter of poles of electromagnet	Location and year of commissioning
M-20	4 MeV, D 2-8 MeV, H	68 cm	Leningrad 1963
U-240	5-70 MeV, H K=140 MeV Heavy ions	240 cm	Kiev 1977
MGC-20	K=5-20 MeV H, D, He-3(+2), He-4(+2)	103 cm	Leningrad (3 шт.), Moscow, Turku, Debrecen, Pyongyang, Cairo 1972-2000
DC-3	3 MeV, D	60 cm	Moscow 1987
RIC-30	30 MeV, H	150 cm	Tver 1992
RIC-14	15 MeV, H	120 cm	Obninsk 1998
CC-18/9	18 MeV, H- 9 MeV, D-	110 cm	Турку, Saint Petersburg Snezhinsk, Moscow 2004-2014
MCC-30/15	30 MeV, H- 15 MeV, D-	150 cm	Jyväskylä 2010
CC-1-3	1-3 MeV, H-	60 cm	Belgrade 2015
C-80	80 MeV, H-	205 cm	Gatchina 2016

The first experience of developing ACS cyclotrons series CC

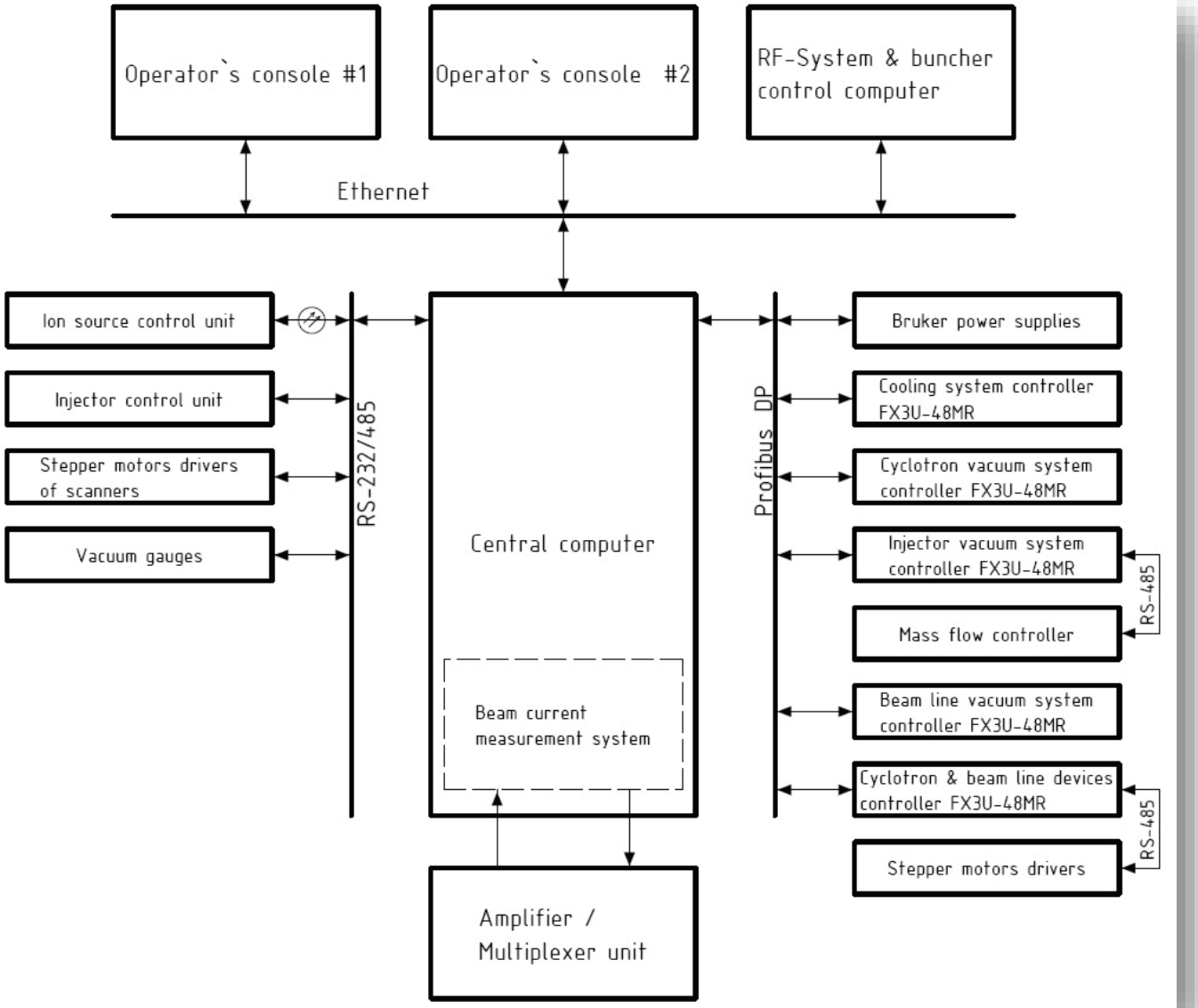


- **Based on the Mitsubihi MELSEC System Q**
- **Interfaces of communication: Ethernet, Profibus-DP, RS-232, RS-485**
- **The central PLC software performs full control of all systems**

Drawbacks of the first generation ACS

- when making changes to the software, all the systems of the cyclotron must be restarted, which significantly slows down the adjustment procedure
- the accuracy of the beam currents measuring is not high because of using standard ADCs
- high radiation level in the cyclotron hall caused the failure some of the electronic equipment

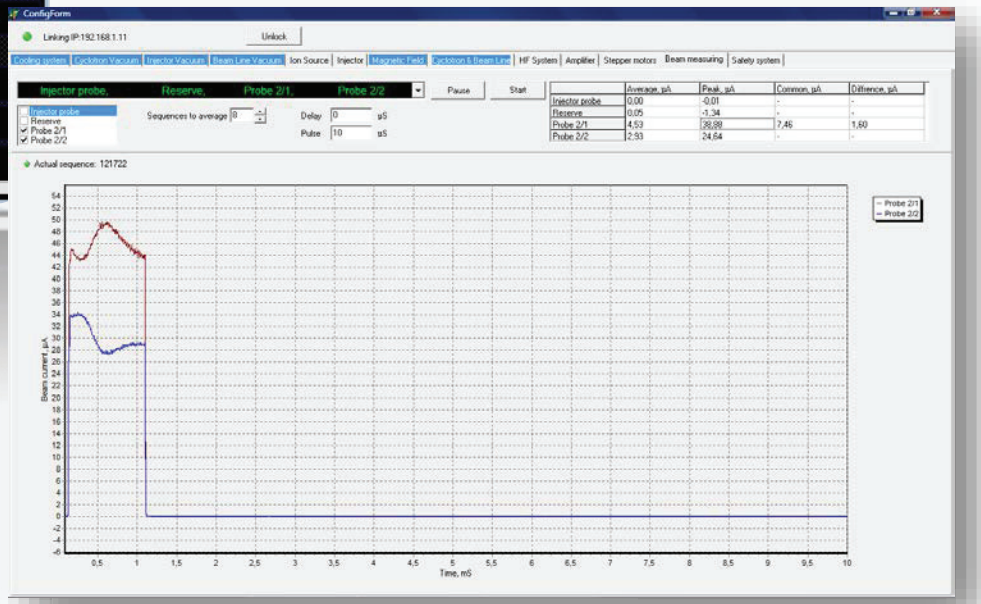
ACS of the 2-nd generation



- **Distributed architecture**
- **Electronic equipment in a radiation-safe place**
- **Advanced RF-system control**
- **A high-quality system to measure the beam currents**

ACS of the 2-nd generation software screenshots

➢ **Main control program window**



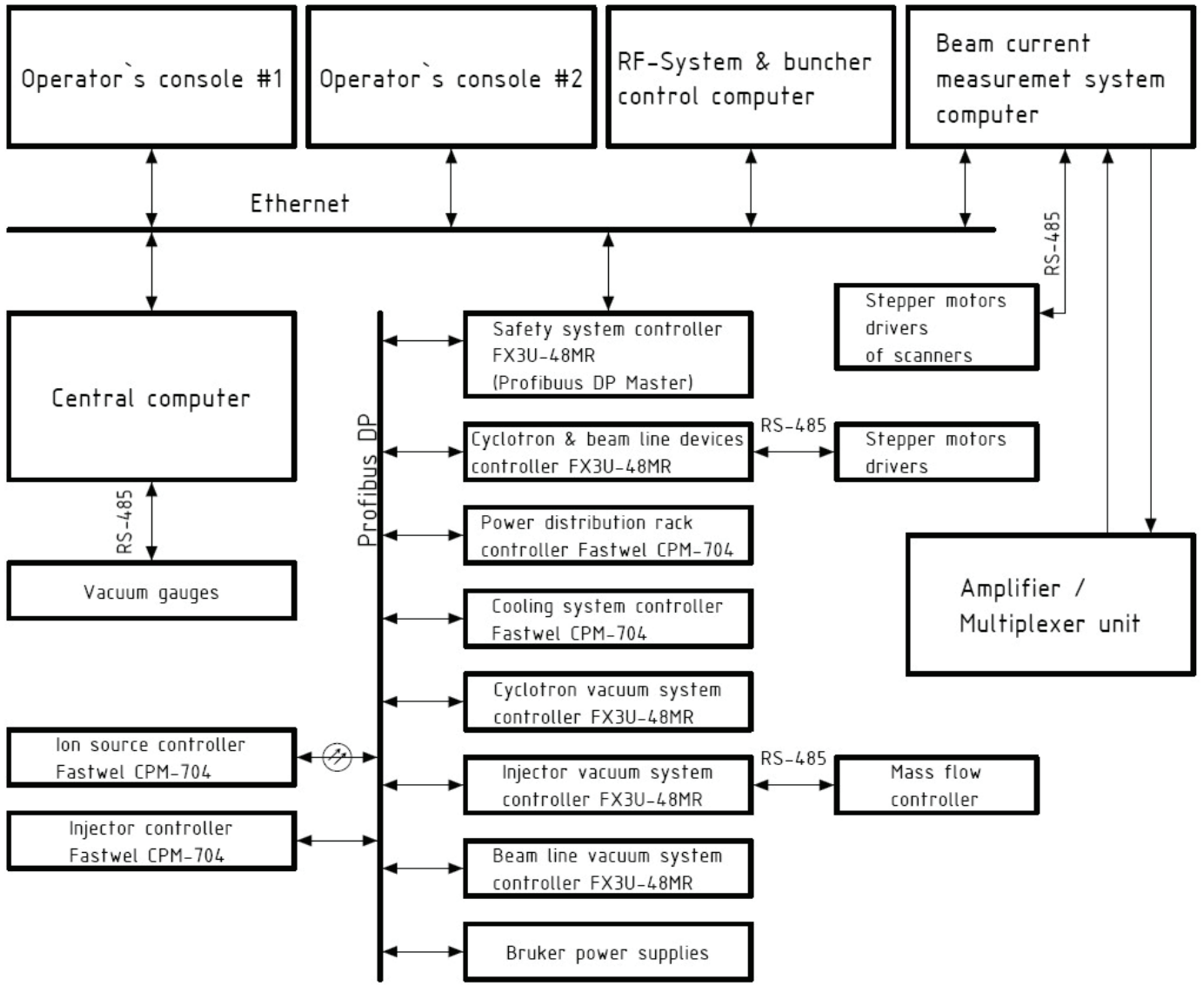
➢ **Beam current measurement software window**

Drawbacks of the second generation ACS

- Under ACS long-term operation, acquisition of data of the current measuring system failed.

- When rebooting the central computer, the Profibus master buffer was cleared.

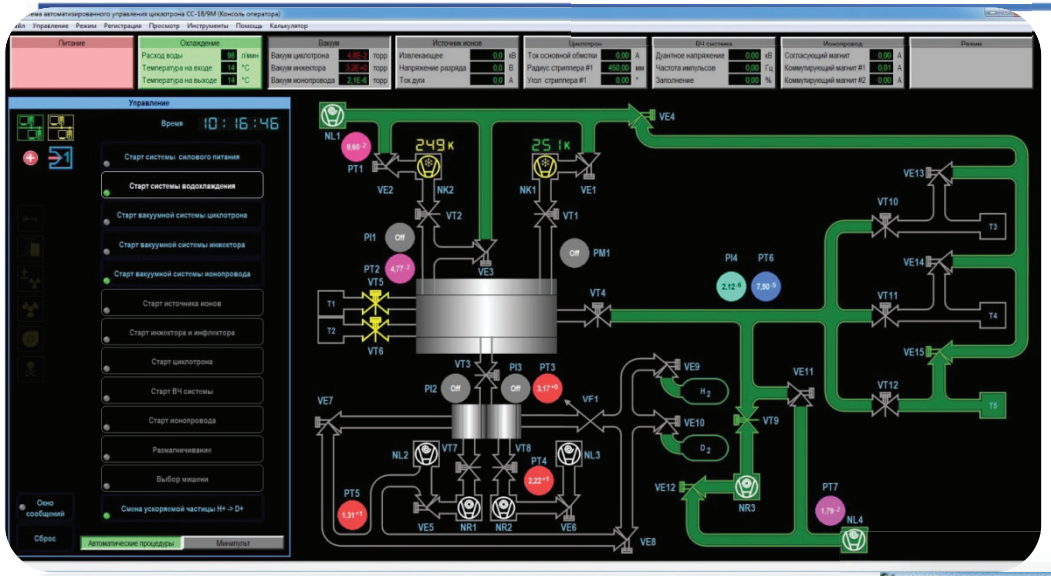
ACS of the 3-rd generation



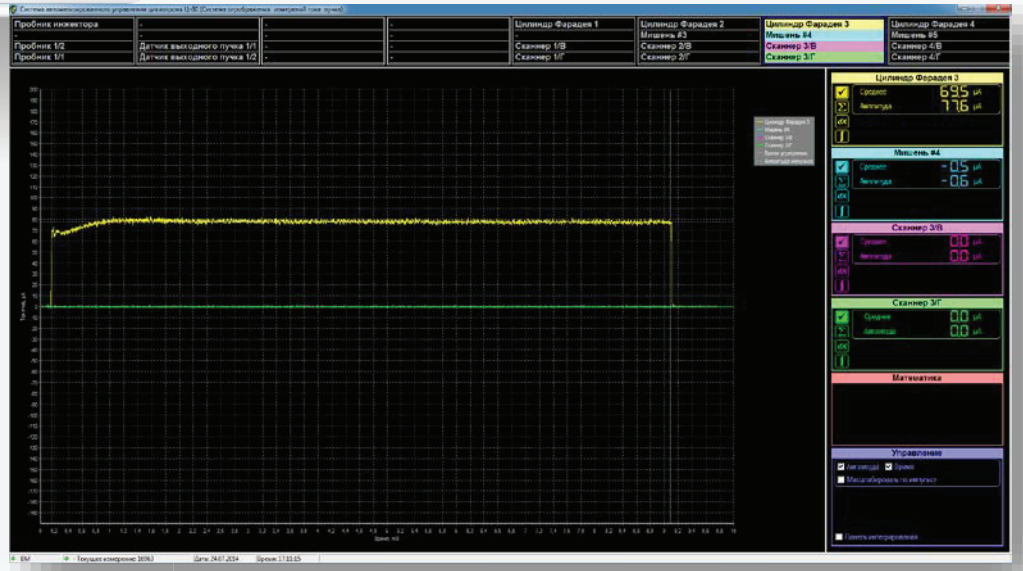
Features of the 3-rd generation ACS

- Advantech controllers and some Mitsubishi FX3U controllers replaced with Fastwell IO.
- Mitsubishi FX3U controller was added, which took over the tasks of the Profibus DP network master and the management of the security and interlocks system.
- More convenient and functional interface of the control program.
- The ADC of the beam current measuring system was moved in a separate computer.

ACS of the 2-nd generation software screenshots



- Main control program window



- Beam current measurement software window

Drawbacks of the third generation ACS

- The bandwidth of the Mitsubishi FX3U controller system bus (the Profibus network master) was insufficient to transfer a necessary volume of data.

ACS of the target system

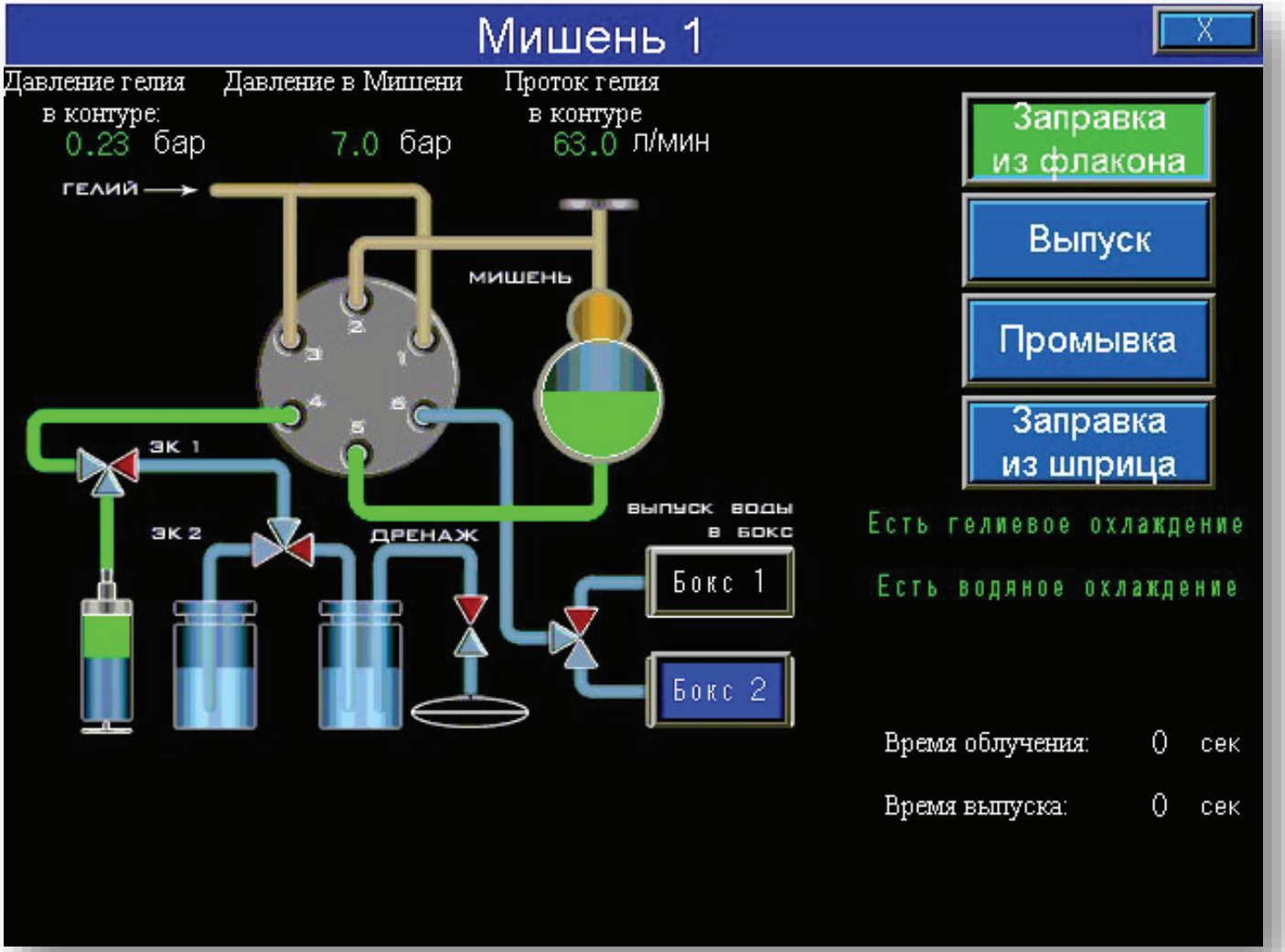
- Since 2014 it is supplied as part of a cyclotron complex
- Fully autonomous system

Mitsubishi GT1275

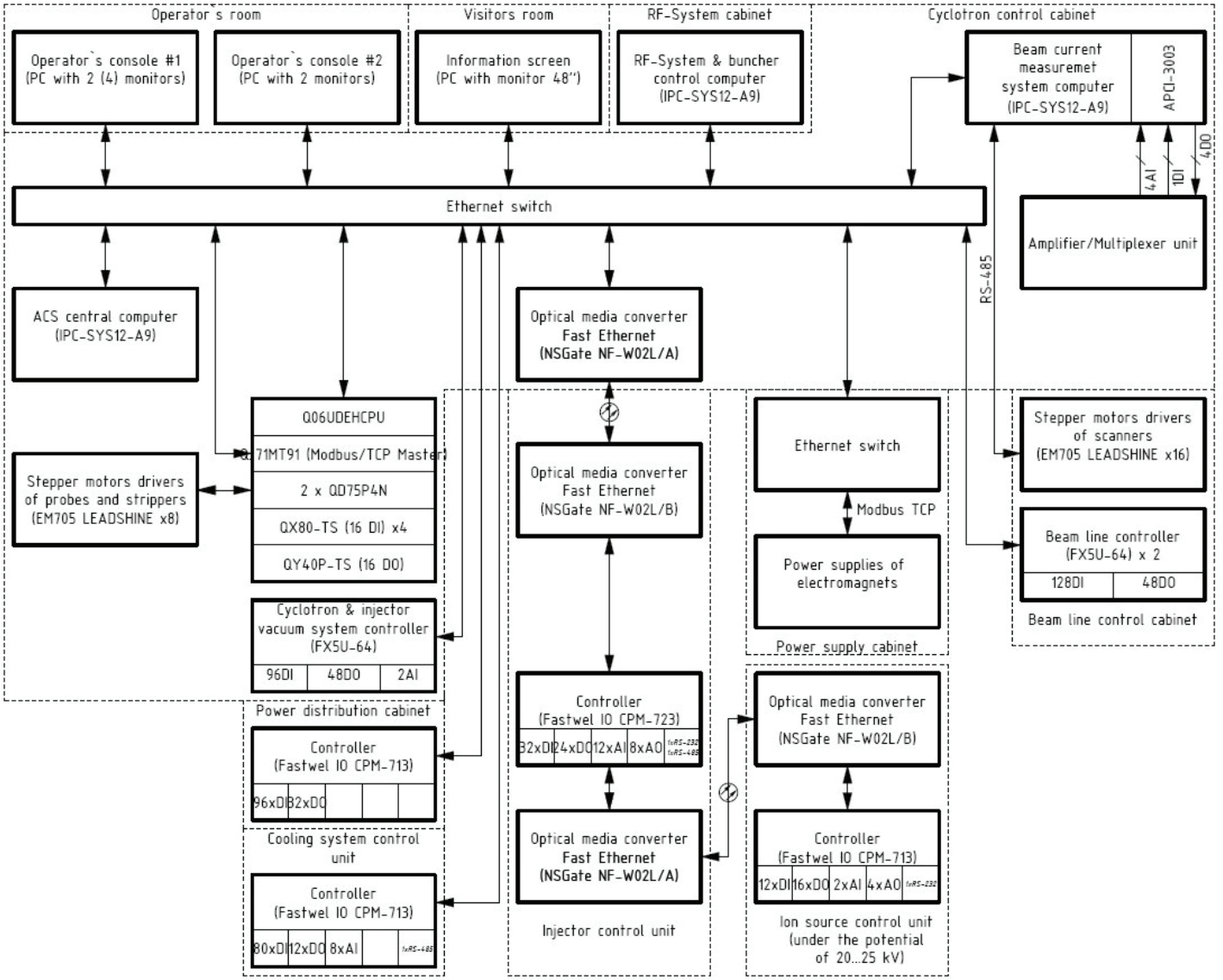
Ethernet

Mitsubishi FX3U

The interface of the ACS by a target complex



Updated ACS for cyclotrons



Features of updated generation ACS

- As the central controller of the ACS, the Mistubishi Q-series controller.
- As the slave controllers - Mitsubishi FX5U and Fastwel-IO.
- Industrial Ethernet (Modbus / TCP) instead of Profibus DP.
- Reduced number of controllers.
- Control of the beam transport line is allocated to a separate rack.
- Extended functionality of the ACS (management of operators access to work, operational journal, displaying a graph of the cyclotron complex main parameters).
- The control subsystem of the target complex is integrated in the ACS.
- It is planned to realize remote control elements for the cyclotron complex via the Internet.

Thank you for attention!