MULTIPURPOSE RESEARCH COMPLEX BASED ON THE INR HIGH INTENSITY PROTON LINAC

A.Feschenko, M.Grachev, L.V. Kravchuk, V.L.Serov
Institute For Nuclear Research, Moscow 117312, Russia

I will talk about:

1. General description and recent status of the Complex (Accelerator and Experimental Area).
2. Main current goals.
3. Some experience of accelerator operation.

Moscow

Troitsk

41 km

MULTIPURPOSE RESEARCH COMPLEX

2 km

RUSSIAN ACADEMY OF SCIENCES

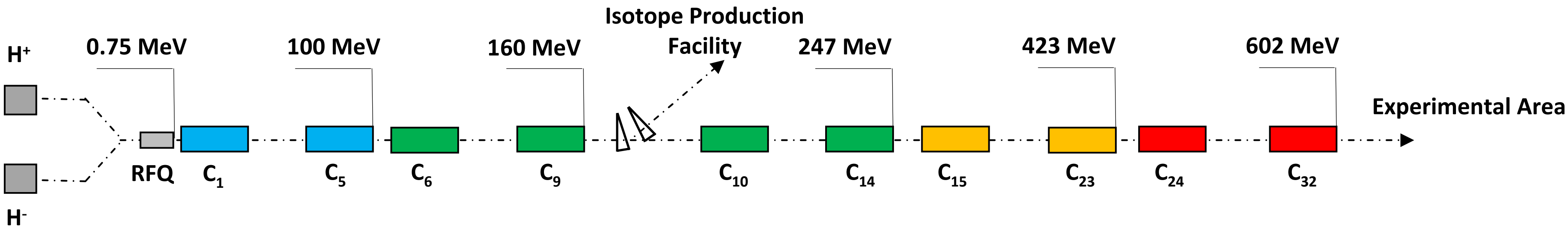
INSTITUTE FOR NUCLEAR RESEARCH

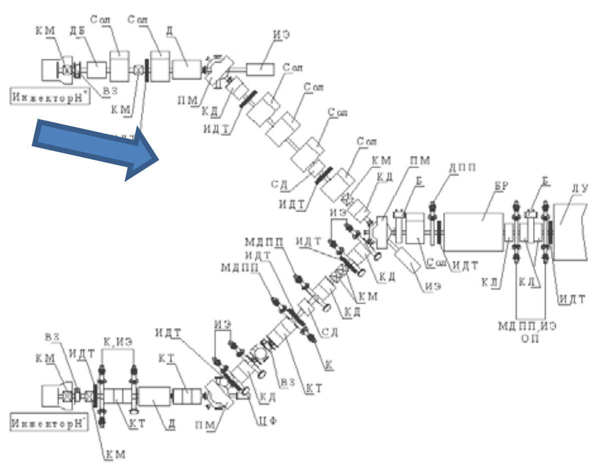
MULTIPURPOSE RESEARCH COMPLEX

What do we mean?

1. Linear Accelerator
2. Experimental Area
    - RADEX facility
    - Spallation neutron source IN-06
    - LNS-100 spectrometer
    - Beam Therapy Complex
3. Isotope Production Facility

Linear Accelerator





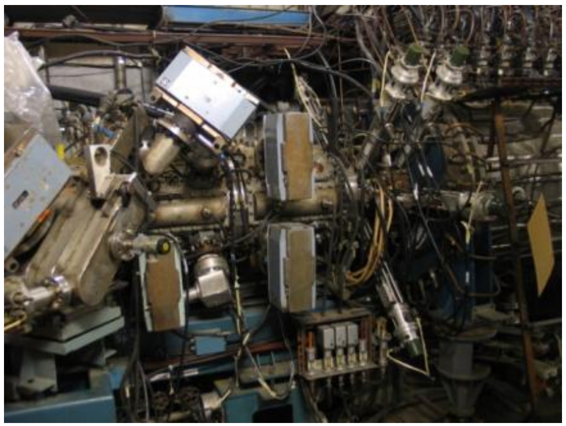
Proton Injector

Injection Lines

Low Energy Part (Drift Tube Linac)

750 keV — 20 MeV — 49 MeV — 74 MeV — 94 MeV — 100 MeV

RFQ — Tank 1 — Tank 2 — Tank 3 — Tank 4 — Tank 5



Booster RFQ

Inside Drift Tube Tank

5 Drift Tube Tanks

Frequency – 198.2 MHz

Output energy- 100 MeV

High Energy Part (Coupled Cavity Linac,100-600 MэB)

27 four-section Disk and Washer cavities

Frequency 991 MHz

Accelerating cavities in the tunnel

Klystron Gallery

Main accelerator parameters

Parameter	Design	Obtained	September 2012
Particles	p, H-minus	p, H-minus	p
Energy, MeV	600	502	209
Pulse current, mA	50	16	15
Repetition rate, Hz	100	50	50
Pulse duration, μs	100	200	0.3÷200
Average current, μA	500	150	130

Accelerator operation

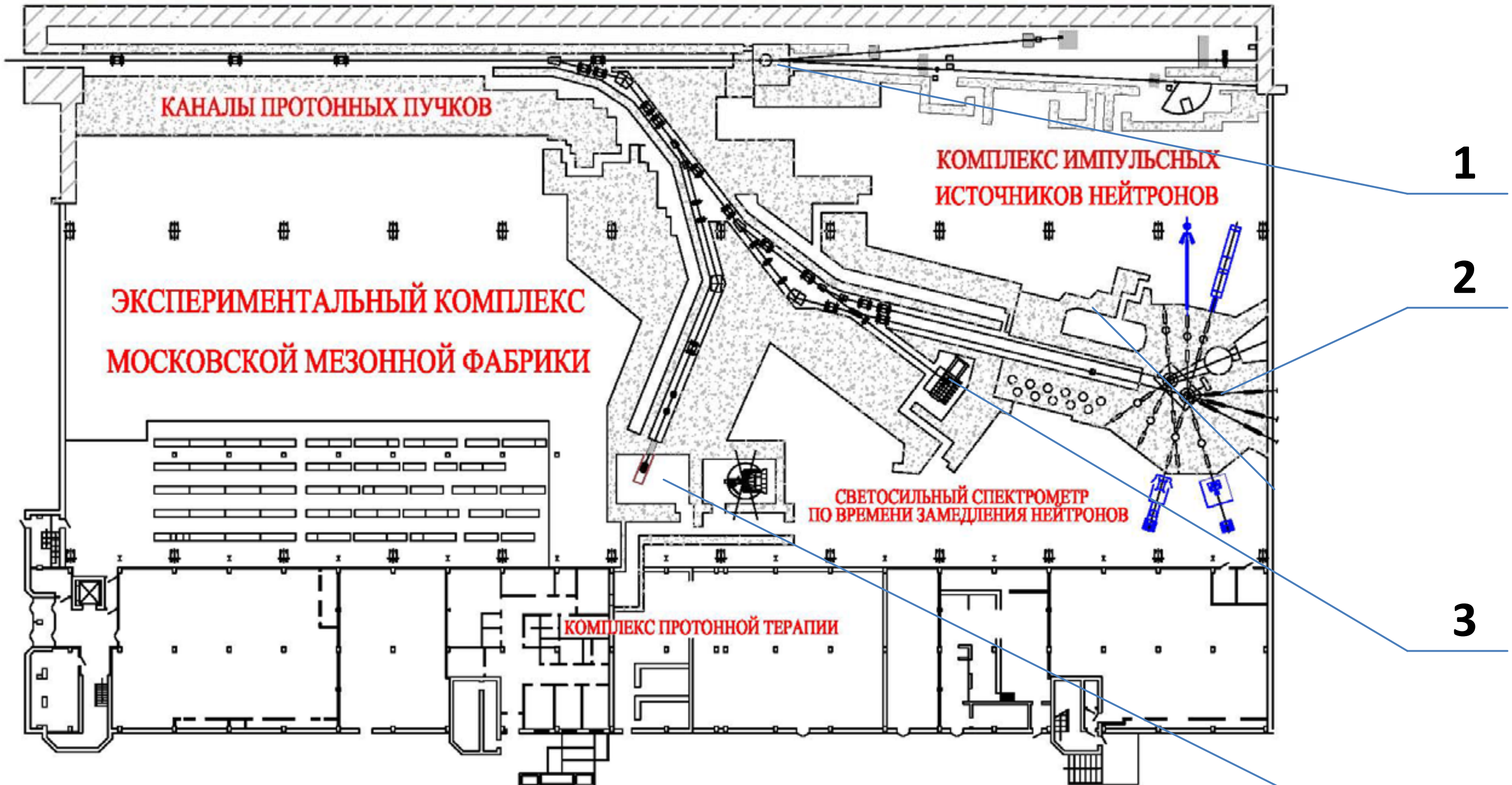
1993 - Beginning of regular accelerator runs

From 1993 till September 2012 - 102 accelerator runs with total duration of 38102 hours

Including:

- **2002 – 1400 hours (6 runs);**
- **2003 – 2400 hours (7 runs);**
- **2004 – 2200 hours (7 runs);**
- **2005 – 1900 hours (6 runs);**
- **2006 – 2250 hours (7 runs);**
- **2007 – 2040 hours (7 runs);**
- **2008 – 1300 hours (5 runs);**
- **2009 – 1208 hours (6 runs);**
- **2010 – 1700 hours (7 runs);**
- **2011 – 1652 hours (5 runs);**
- **2012 – 1050 hours (3 runs);**

Experimental Area



1 - RADEX facility

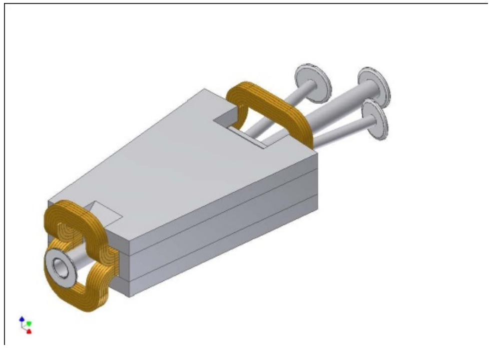
2 - Spallation neutron source IN-06

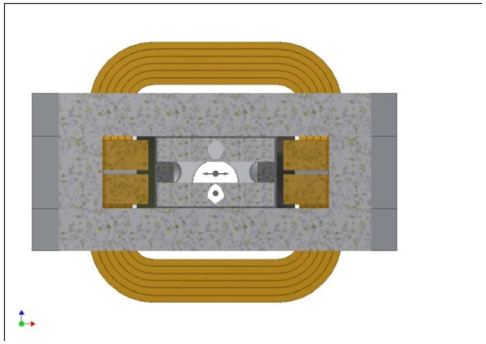
3 - LNS-100 spectrometer

4 - Beam Therapy Complex

Experimental Area. Resent results.

1. Proton and H-minus beams separation system.





Lambertson Septum Magnet

2. Energy Adjustment system in Proton Therapy beam line.

With wedge-shape degrader. Fine energy adjustment within the range of 209÷70 MeV.

M.I.Grachev et al. Proton Channel that Provides Simultaneous Independent Operation of a Treatment Room of Proton Therapy and Neutron Sources of the Experimental Complex INR RAS, WEPPC051

The main goal for the nearest future for the accelerator is improvement of accelerator efficiency

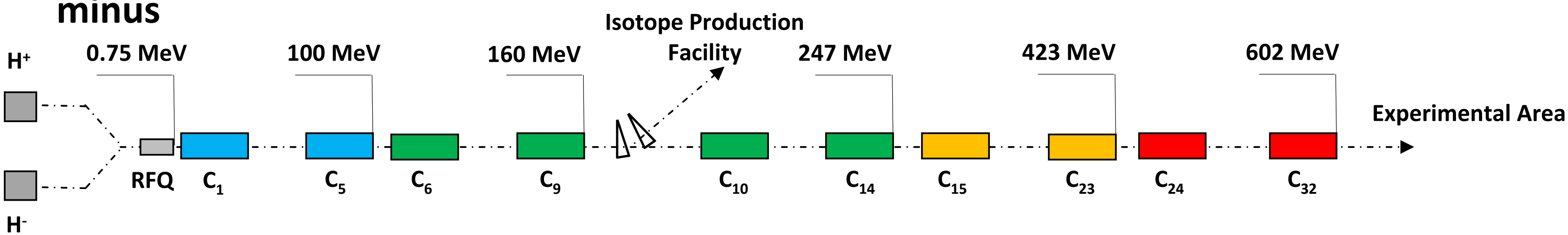
Improvement of Accelerator Efficiency

Increasing the beam pulse repetition rate from the current 50 Hz to 100 Hz

Distribution of the beam between IPF and Experimental Facility

Injector
a) 100 Hz Protons
b) 50Hz protons + 50Hz H-minus

RF System



RF System.
The main problems in DTL RF system

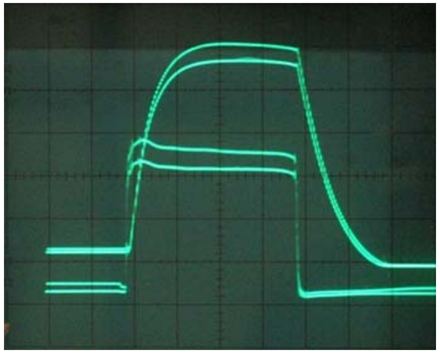
Doubling of average RF power, dissipating in vacuum grid tubes, anode-grid and cathode-grid resonators of RF power amplifiers, coaxial feeder, drift tubes cavities, numerous RF junctions etc.

Increasing the cavity warm-up time after switching off the RF power due to breakdowns or other reasons.

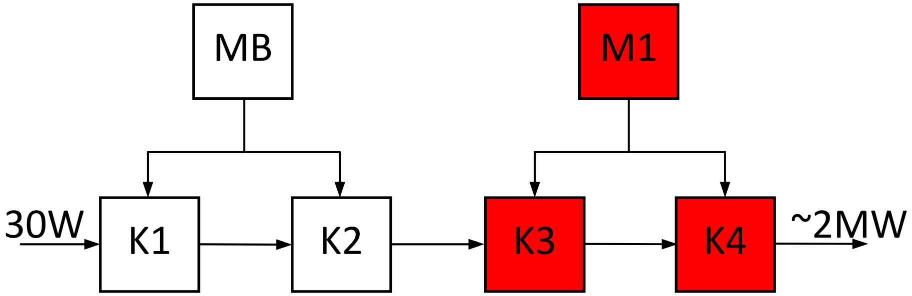
Increasing of high voltage in the pulse-forming lines of the modulators.

50 Hz modulation of a 100 Hz RF pulse sequence.
A.N.Drugakov et al. Investigation of INR Linac DTL RF System Operation at 100 Hz Repetition Rate, MOPPA023

50 Hz modulation of 100 Hz RF pulse sequence.

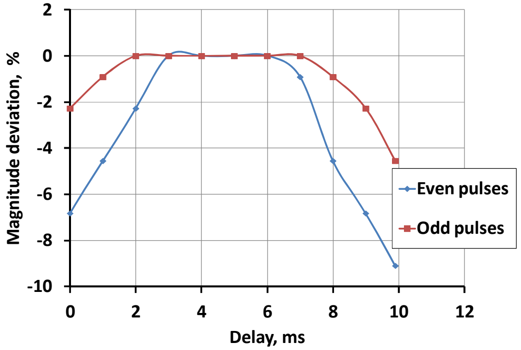


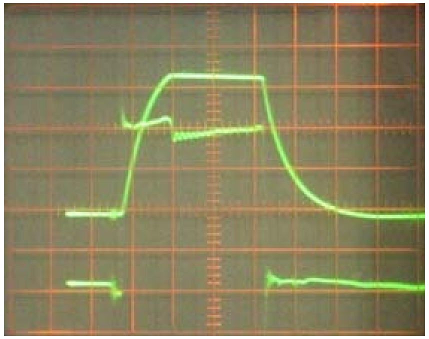
Envelopes of RF field in accelerating cavities (upper beam) and stages K3-K4 anode pulses (lower beam)



Block diagram of DTL RF channel.
Red colour – tubes with directly heated filaments by AC current

After proper phasing of filament heating currents

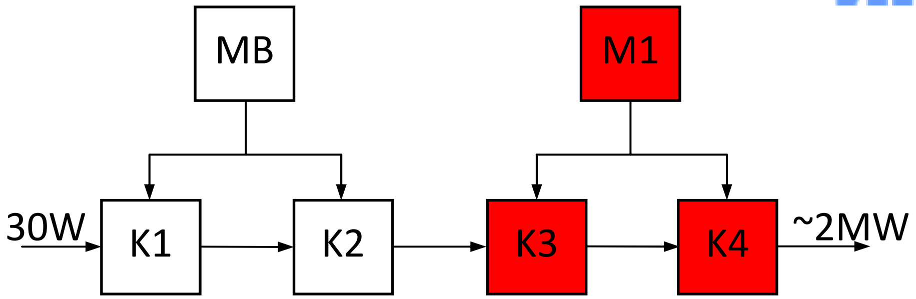




Some other problems with RF system

DTL RF system:

Stopping of production of grid tubes for
M1 - GMI-44A
K3 - GI-51A
K4 - GI-54A

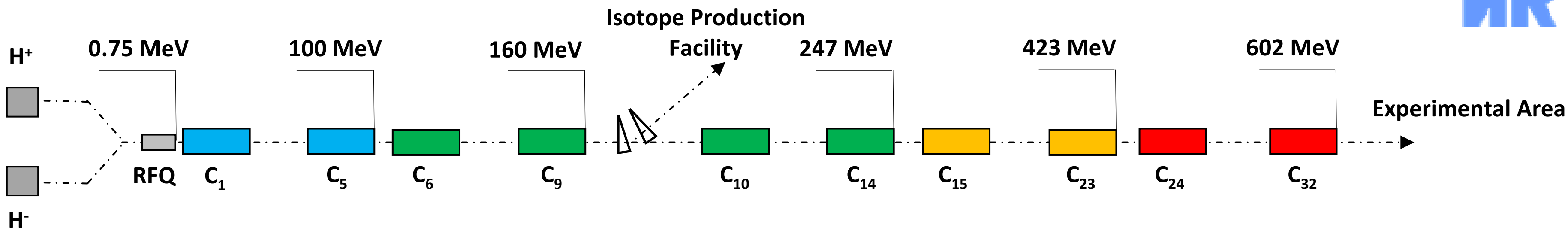


Solution:
Replacement of GI-51A by GI-57A
GI-54A by GI-71A
Restoration of GMI-44A (S.E.D.-Spb)

Status of INR DTL RF System, MOPPA022

CCL RF system: Deficiency in klystrons. The capabilities of industry to produce the klystrons enable to balance at the level of 209 MeV.

Distribution of the beam between IPF and Experimental Facility



Development, fabrication, installation and commissioning of the Beam Pulse Separation System for intermediate beam extraction area (160 MeV)

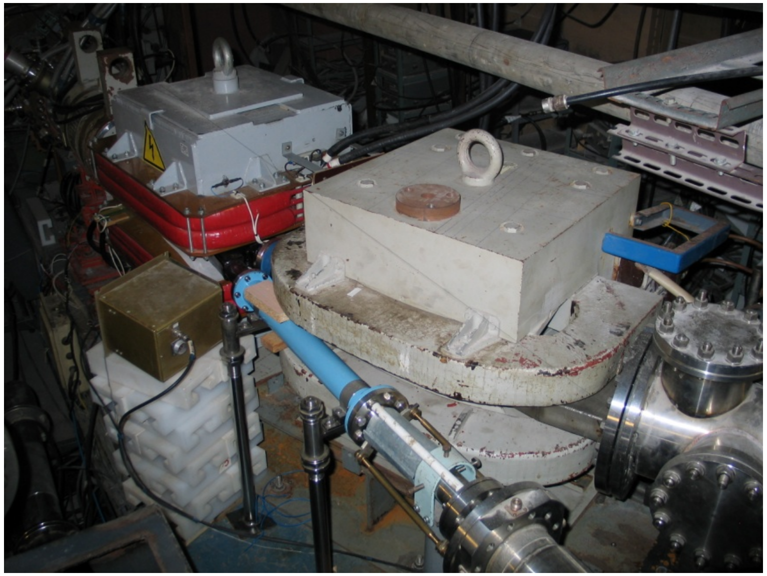
Frequency – 50 Hz

Up to 50 Hz to IPF

Full beam to IPF in DC mode

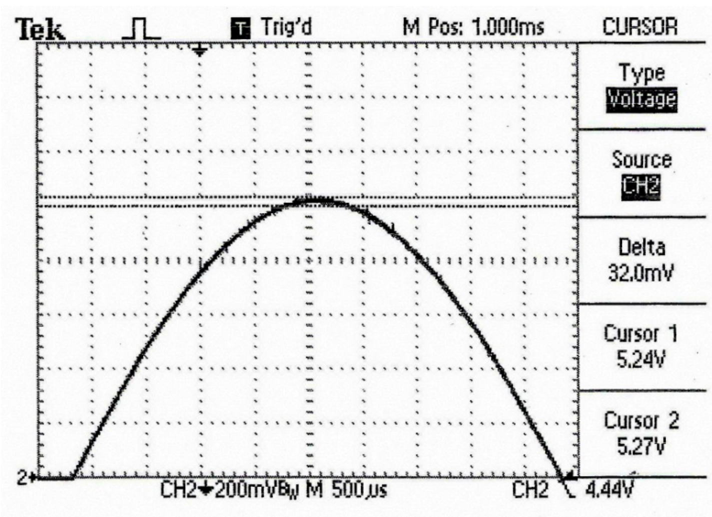
B.O. Bolshakov et al. Power Supply System of the Pulse Bending Magnet for the Linear Accelerator Operated at the Moscow Meson Factory, WEPPC034

N.I.Brusova et al. Beam Pulse Separation System of INR Linac, WEPPC003

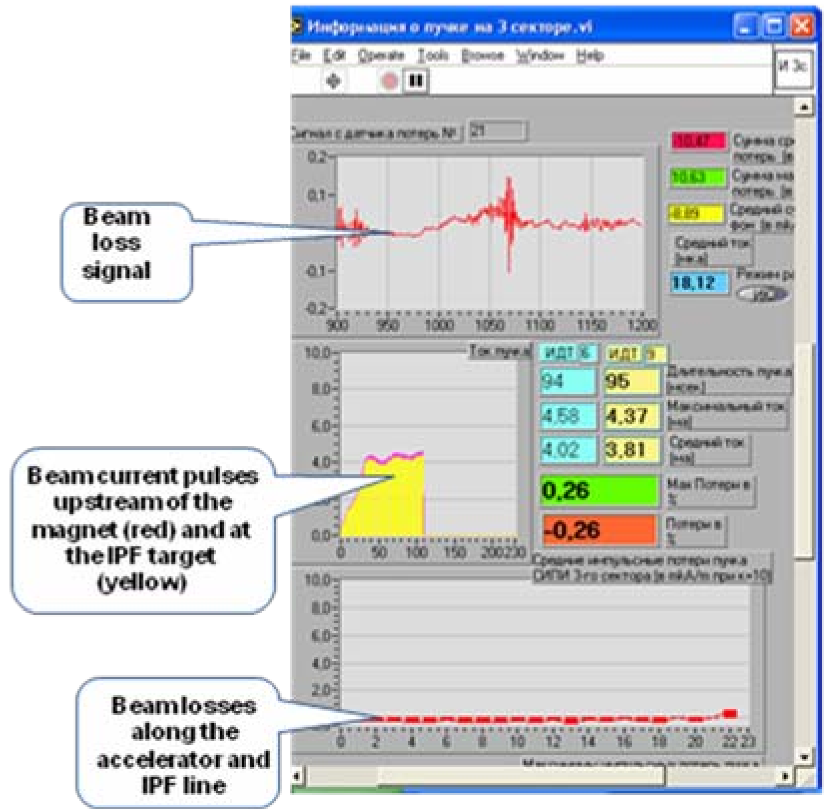


Pulse and DC Magnets in Intermediate Extraction Area

Glass vacuum chamber for Pulse Magnet



Top of the current pulse

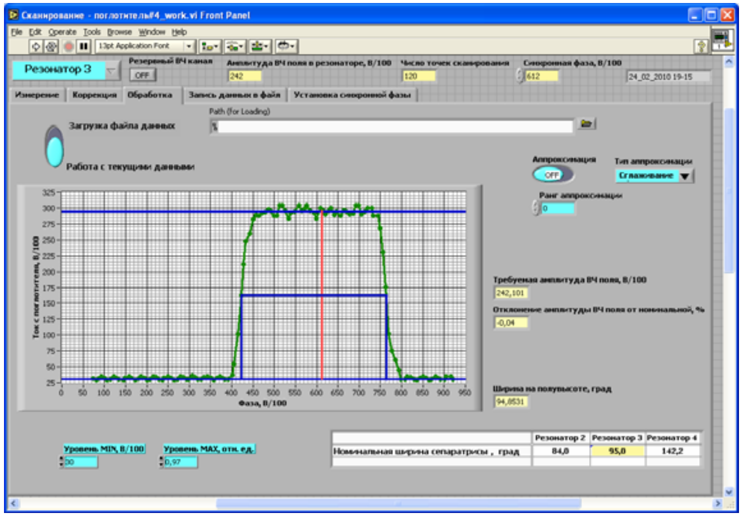


The first pulse magnet test with beam

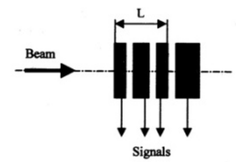
PECULIARITIES OF ACCELERATOR TUNING

- Longitudinal tuning
- Transverse tuning
- Beam loss minimizing

Longitudinal tuning



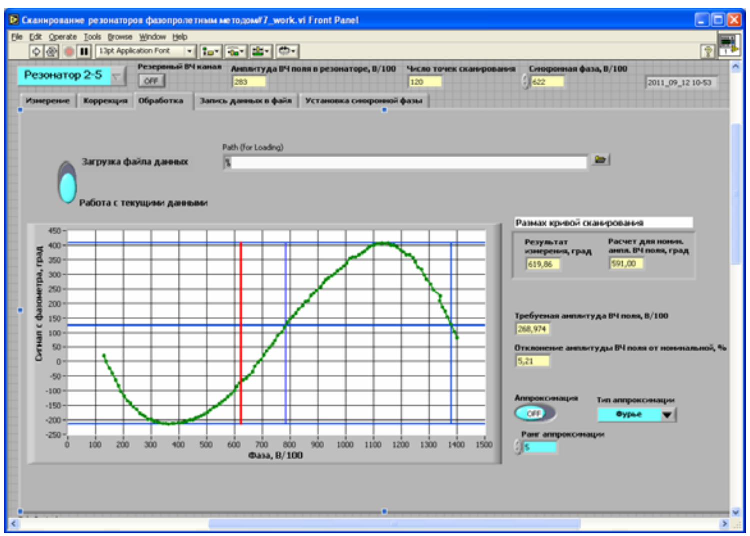
Phase scan of DTL Tank with degrader-absorber



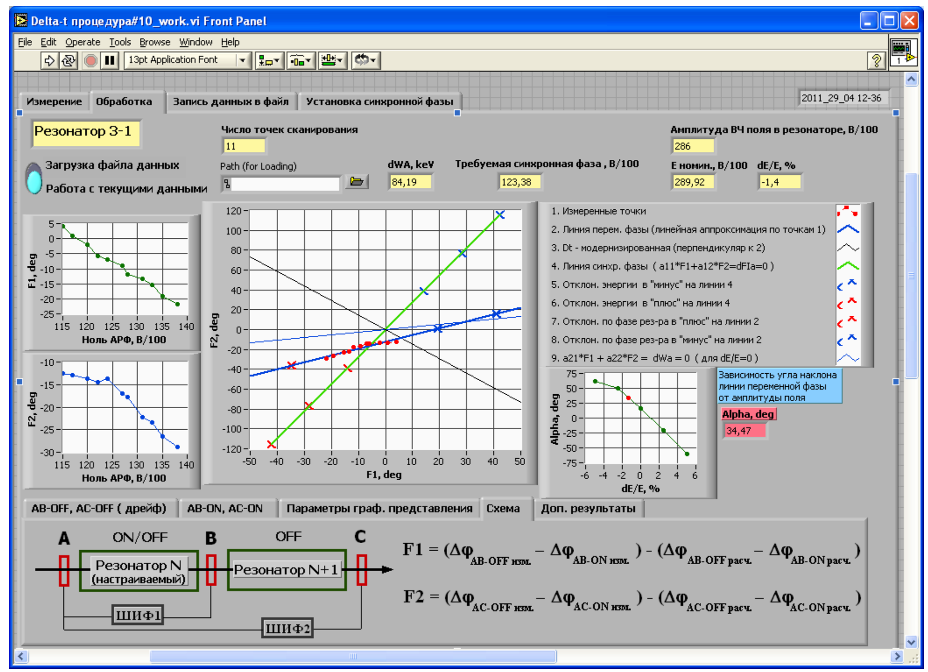
Phase scan parameters

Tank #	Wo, MeV	W absorb. MeV	L, mm	Φ, deg	k
1	20			114	0.412
2	49	42.5	3.0	84	0.387
3	74	68.6	7.0	95	0.445
4	94	84.6	10.0	142	0.553
5	100	110.0	16.0		

Beam degrader-absorber at the exit of DTL Linac



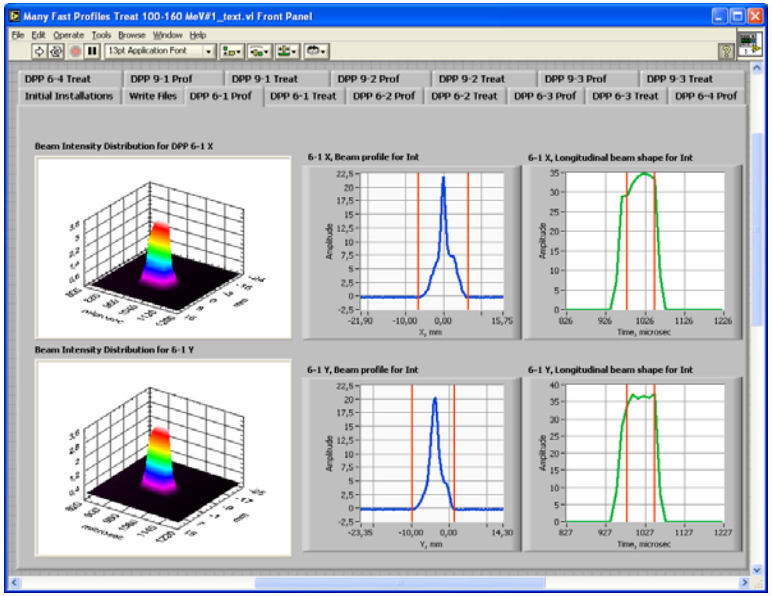
Phase scan of DTL Tank 5 with two current harmonic monitors

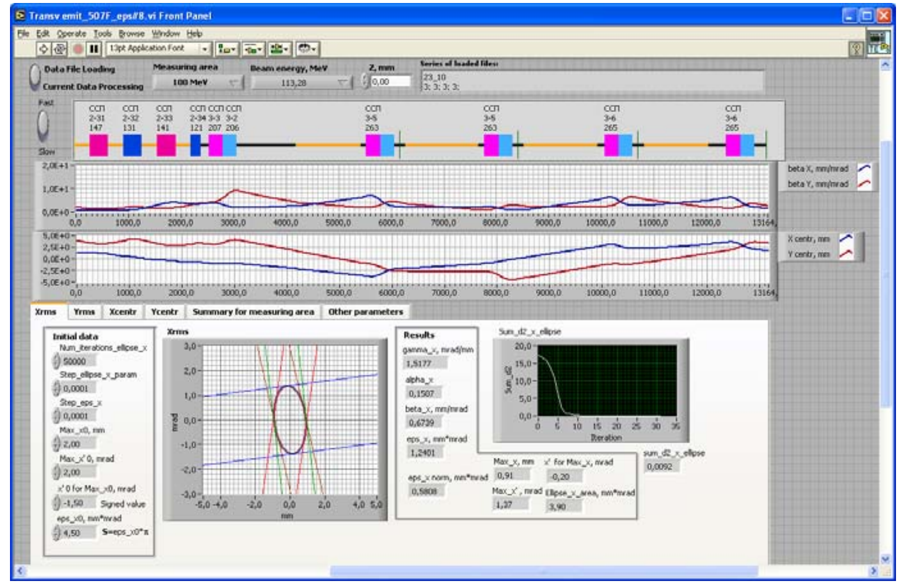


ΔT procedure in CCL cavity

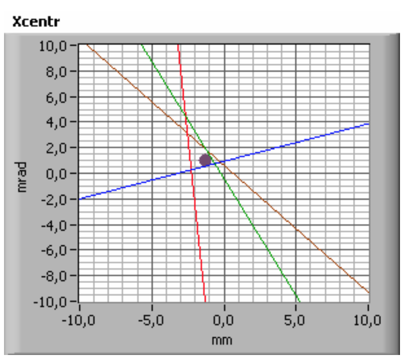
Transverse tuning (5 matching-correction areas)

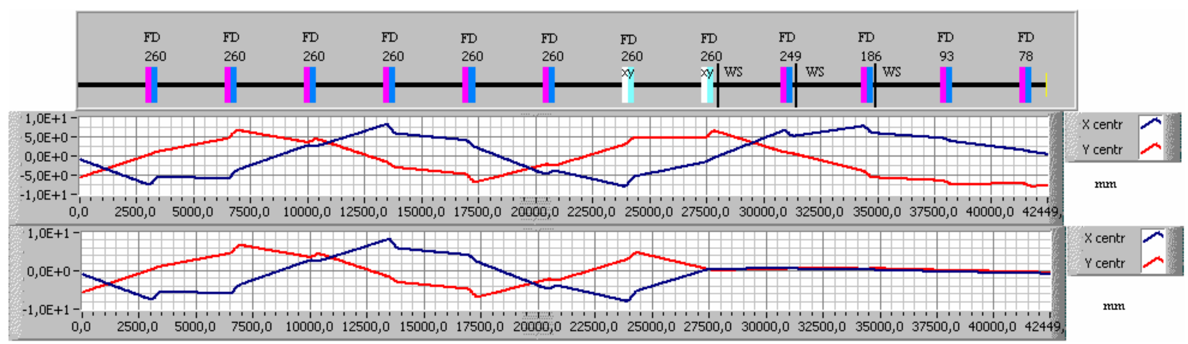
Matching





Correction





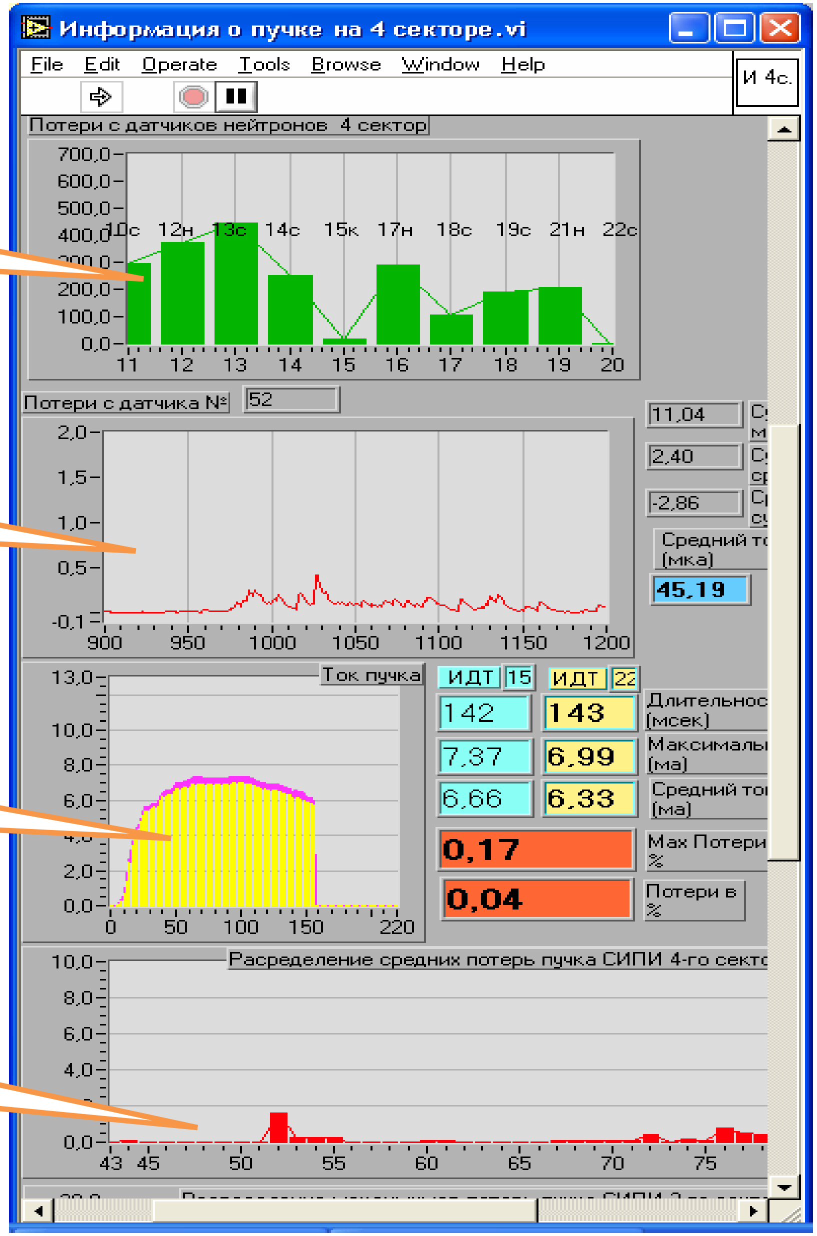
Beam loss minimizing

Neutron Detectors

Beam Loss PMT Signal

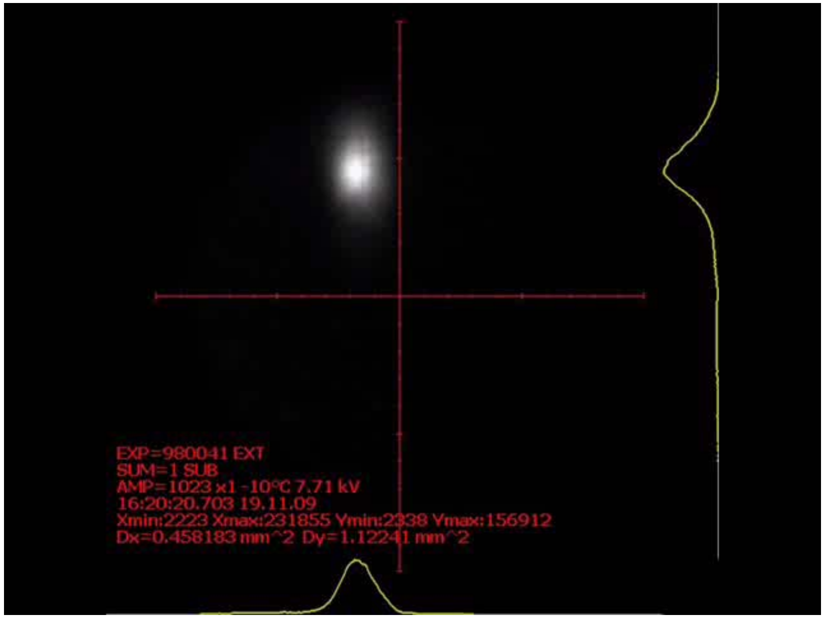
Beam Current Signals

Beam Loss Along Sector #4



Beam loss information in Sector #4 of accelerator (247-423 MeV)

Continuous observations of beam cross section



Emittance Measurements at the Exit of INR Linac, WEPPD055

Conclusion

1.Multi-purpose Scientific Complex based on high intensity Proton Linac is in operation at the Institute for Nuclear Research.

2.Permanent modernization of the accelerator and the Experimental Area enables not to only to maintain the complex in operational state but also to improve beam parameters and complex capabilities.

3.The existing experimental facilities are the basis for variety of both basic and applied researches.