Status of the Nuclotron

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VBLHEP JINR

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- Statistics of the operation in 2012 - 2014
- Increase of the beam energy
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Statistics of operation

Run #46 11-12.2012 (793 h 67% beam time)
Test of NICA control system based on TANGO

Run #47 02-03.2013 (860 h 70% beam time)
Acceleration and slow extraction d 4.5 GeV/u (~ 1.8 T)
Stochastic cooling of d beam
shortest beam spill 60ms at high intensity

Run #48 11-12.2013 (1050 h 73% beam time)
Carbon ions were accelerated and extracted at energy 5.8 GeV/u, $1*10^9$
Stochastic cooling of C coasting and bunched beams
Beam spill 20 s

Run #49 02-03.2014 (650 h 66% beam time)
Double user mode (first run at Nuclotron).

Run #50 05-06.2014 (650 h 31% beam time, source and LU20 ~ 43%)
First operation of stand ESIS
Experiments "^{40}Ar" 1.2 GeV/u, "^{7}Li" 3 Gev/u

Cooling ~ 120 h, preparation of all systems ~ 50 – 100 h

Statistics of operation

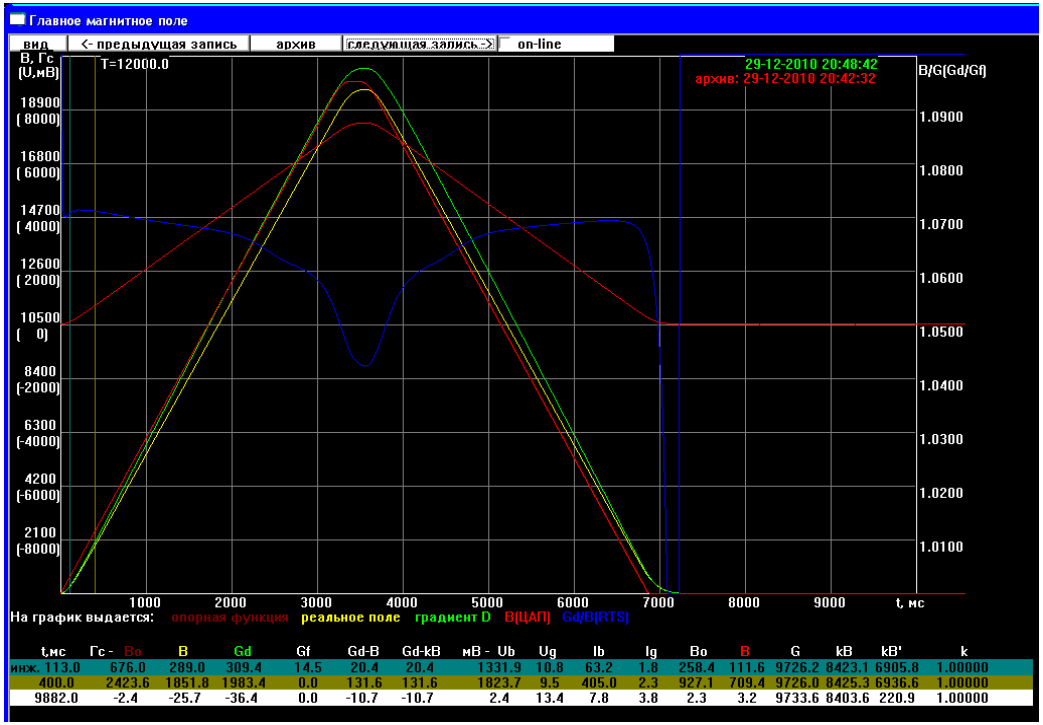
About 25% of the beam time – Machine development:

- test of new equipment (power supply, diagnostics, control system …)
- optimization of beam dynamics (two plateaus, energy increase …)
- R&D for NICA elements and regimes (stochastic cooling, long plateau …)

Average time loss < 5%

Increase of the beam energy

Run #42 (December 2010) – stable and safe operation of the magnetic system at 2 T



Run #44 (December 2011) – Carbon acceleration up to 3.42 GeV/u deuterons: at acceleration up to 4 GeV/u (1.5 T) – problem with Lambertson magnet

Run #45 (March 2012) the problem was fixed, demonstration of possibility of the beam acceleration and extraction at 4.5 GeV/u (1.8 T).

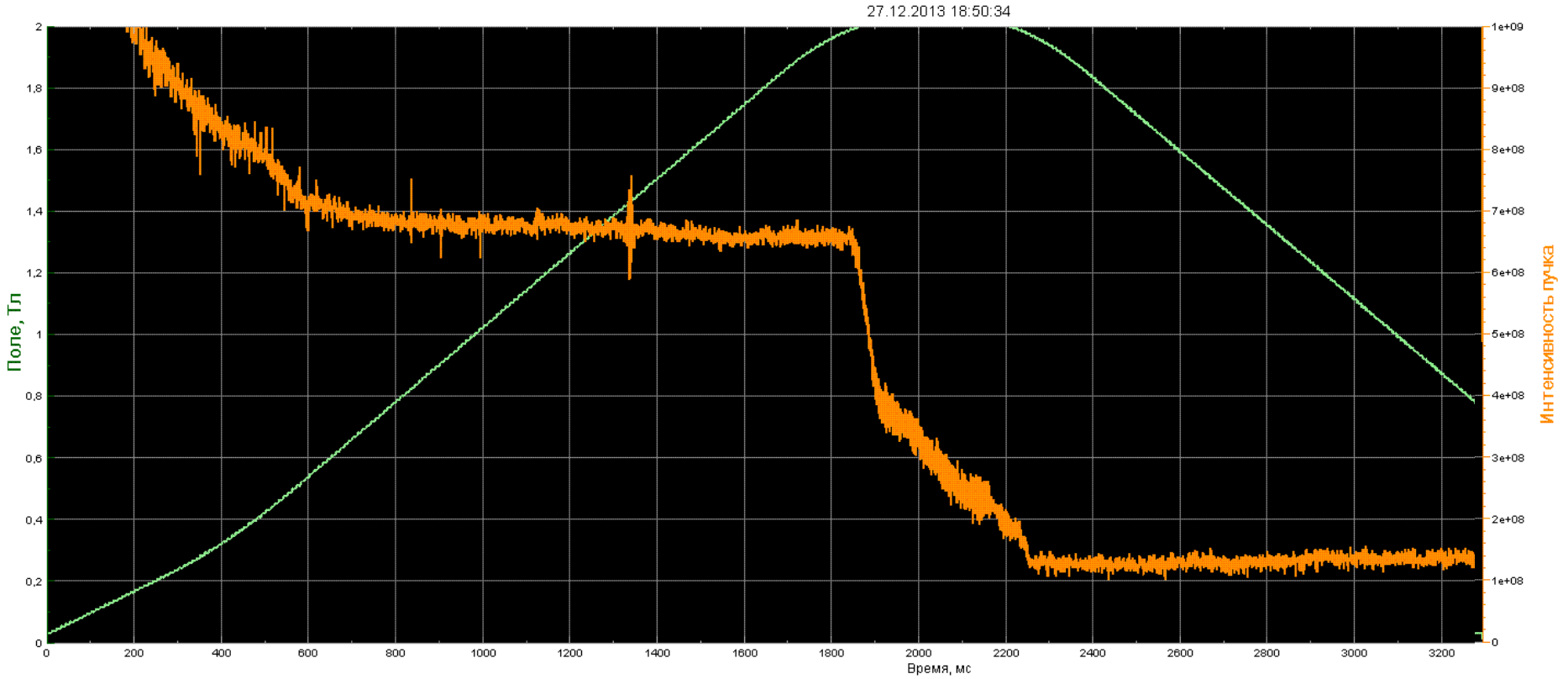
Increase of the beam energy

Run #46 (December 2012) – new control system for quench detectors
intensive test of all systems at fields up to 2 T
Malfunction of powerful current lead.

Run #47 (March 2013) stable acceleration and extraction at 4.8 GeV/u,
at 5 GeV/u – discharge of insulator in ESS
Efficiency of the beam extraction without ESS is below 20%

Run #48 (December 2013) beam acceleration and extraction at 2 T

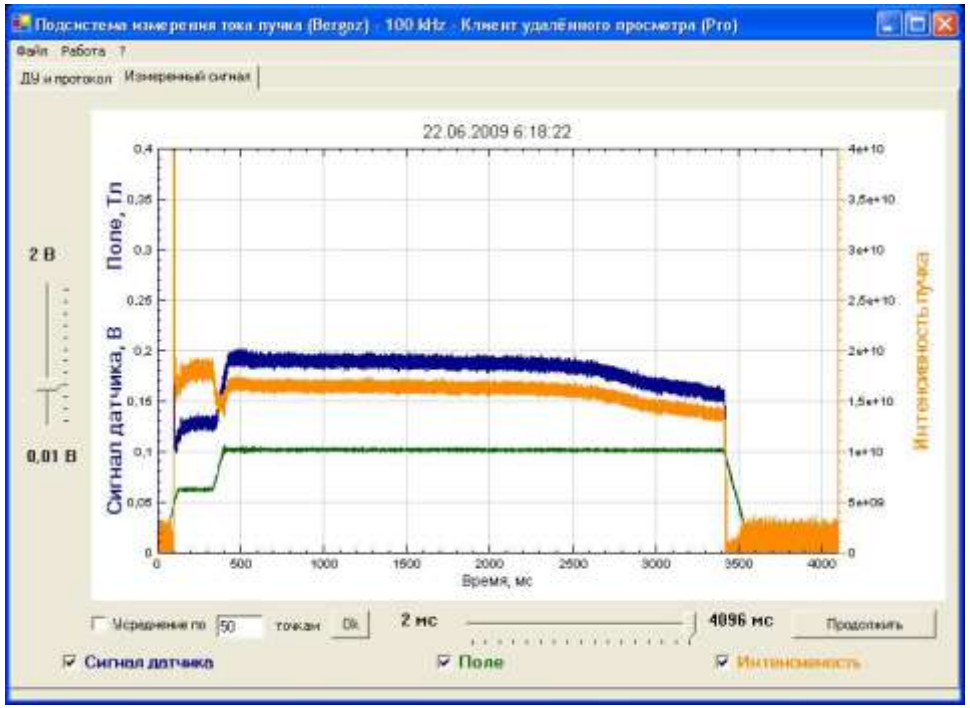
Run #48, carbon beam, 2 T



Stable operation of cryogenic complex,
Better cooling and upgrade of critical elements,
New quench detection system

Operation with two plateaus

Run #39 (June 2009) – new field control system: operation with two (n) plateaus

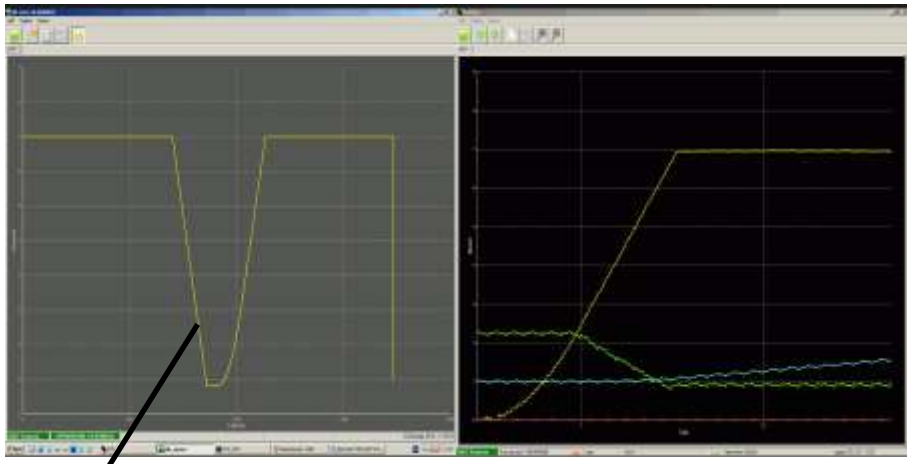


RF is on
during active part of the cycle

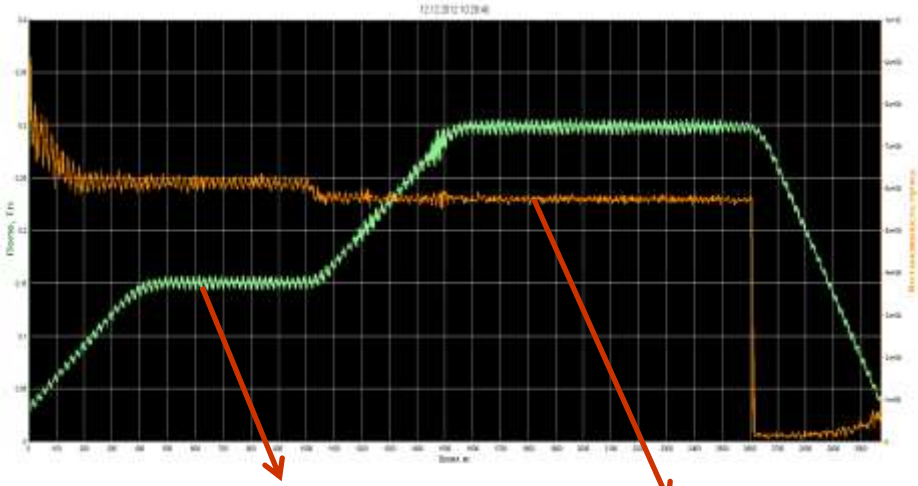
The goal of development is to have coasting beam at both plateaus

Coasting beam at two plateaus, Run #46

Adiabatic debunching and recapture at efficiency of about 95% was demonstrated



RF amplitude



Magnetic field

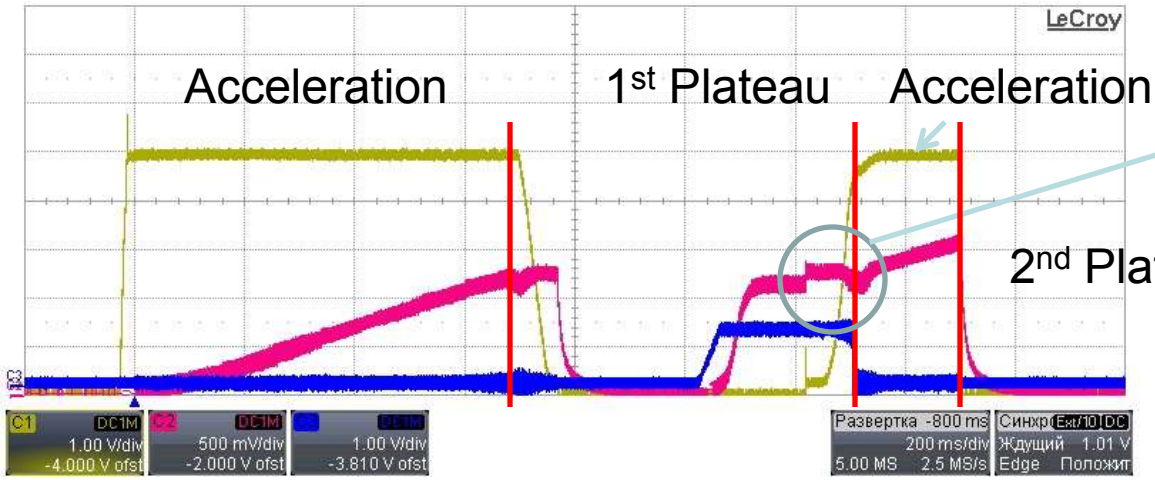
Beam current

Technical limit of the first plateau duration was 0.5 s

Coasting beam at two plateaus, Run #48

Preparation of Operation for two parallel users

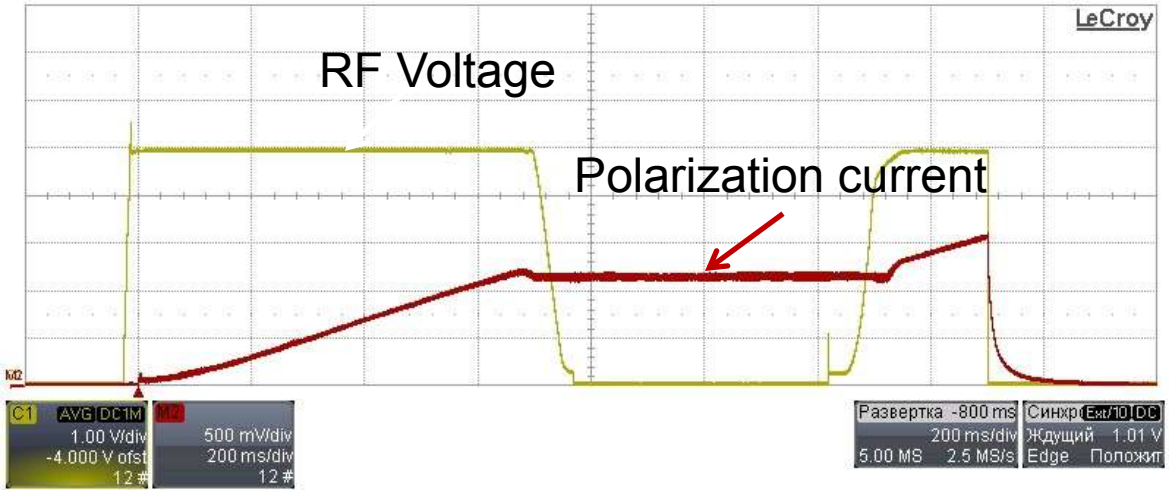
Before modernization



Particle losses

2nd Plateau

After modernization



Efficiency of the re-bunching:

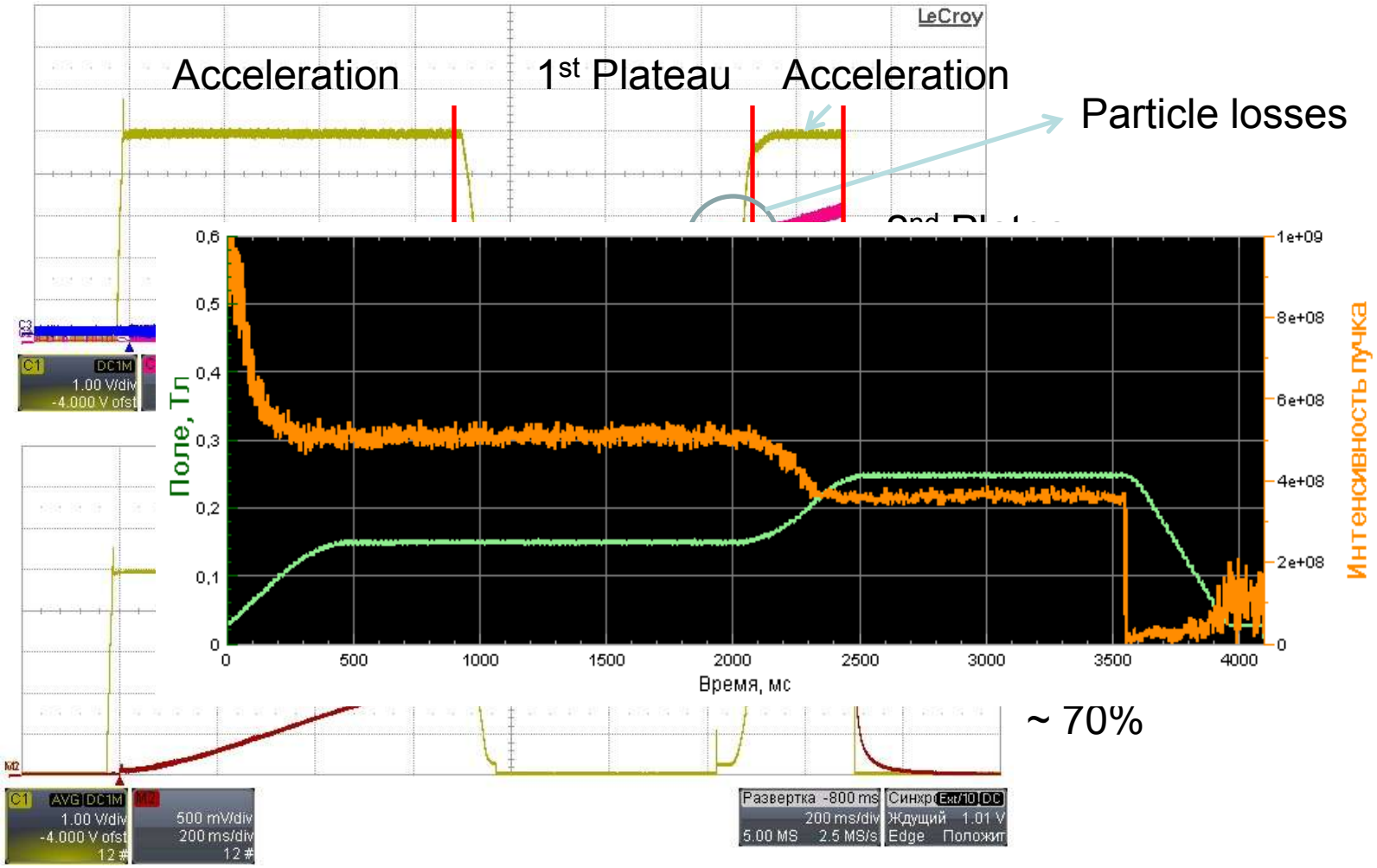
~ 70%

Coasting beam at two plateaus, Run #48

Preparation of Operation for two parallel users

Before modernization

After modernization

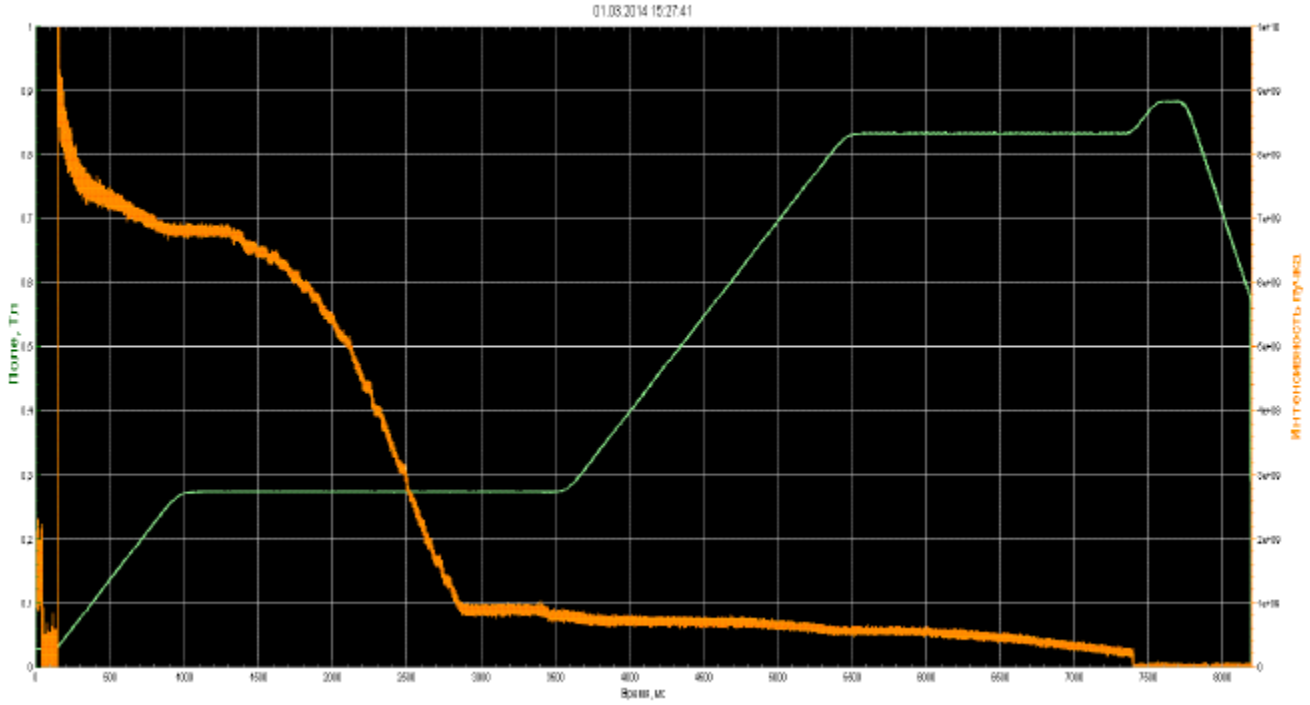


bunching:

~ 70%

Run #49, routine operation

RF is frozen at the first plateau



More accurate optimization of the beam dynamics is necessary
Operation at higher field ramp – to improve duti factor

New laser ion source (LIS)

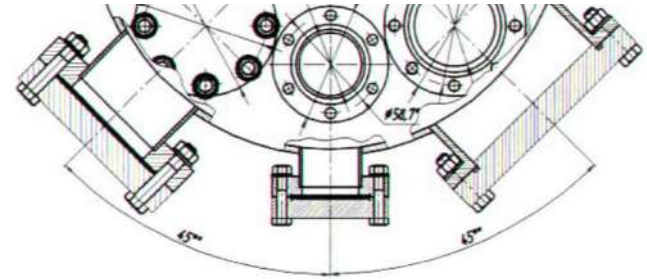
New Nd-YAG laser, instead of the old CO_2 laser

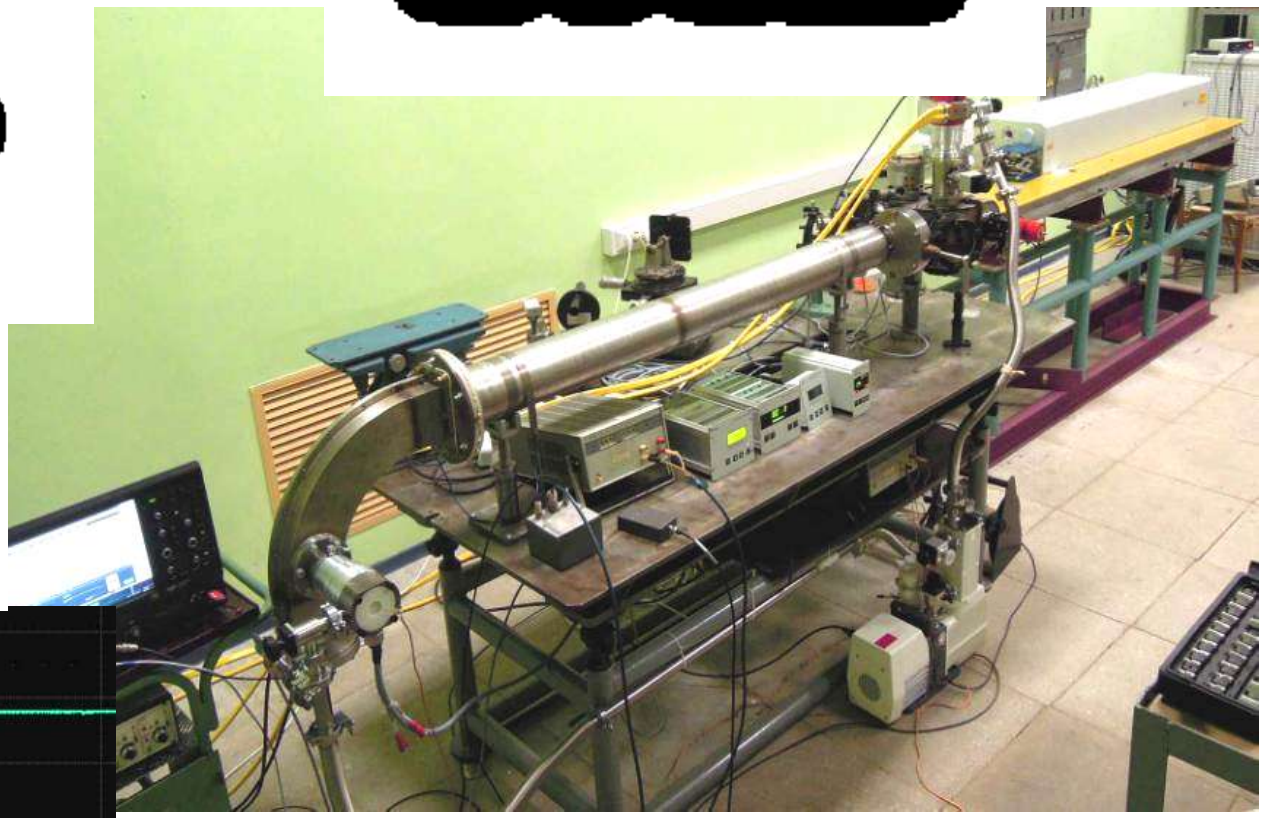
$E \geq 2$ J , $\tau \approx$ 7-8 ns, ~ $5 \cdot 10^{12}$ W/cm²

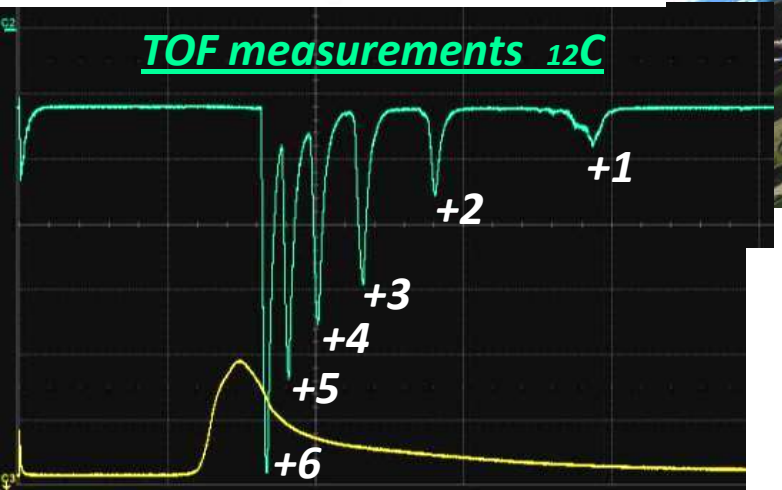
Acceleration of $_{12}C^{6+}$ without stripping

New LIS Test bench

New LIS chamber is under construction







Autumn 2013

First results: $_{12}C^{+6}$ ion beam, 2us, ~3mA

Run #48, December 2013

Old LIS chamber

New Laser at LU-20

The source and LU20 were optimized for C^{+5} acceleration

Current up to 3 mA
Pulse duration ~ 4 μs

Accelerated beam intensity up to $2*10^9$

Krion-6T Electron String Ion Source – stand prototype for Krion-N(ica) ion source.

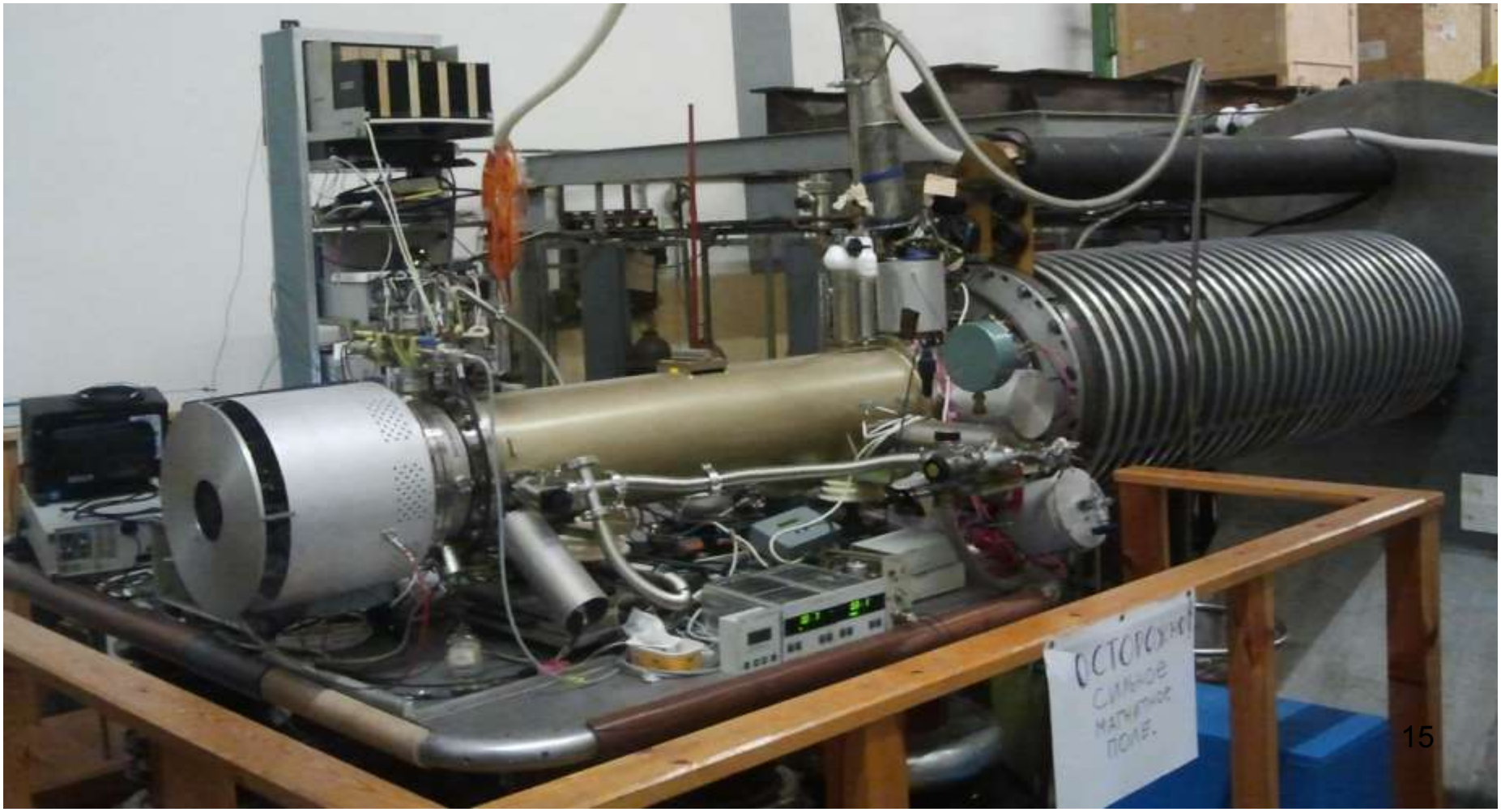
Krion-6T project main parameters: magnetic filed up to 6.0 T, electron energy up to 15 keV.

Expected ion beam parameters:

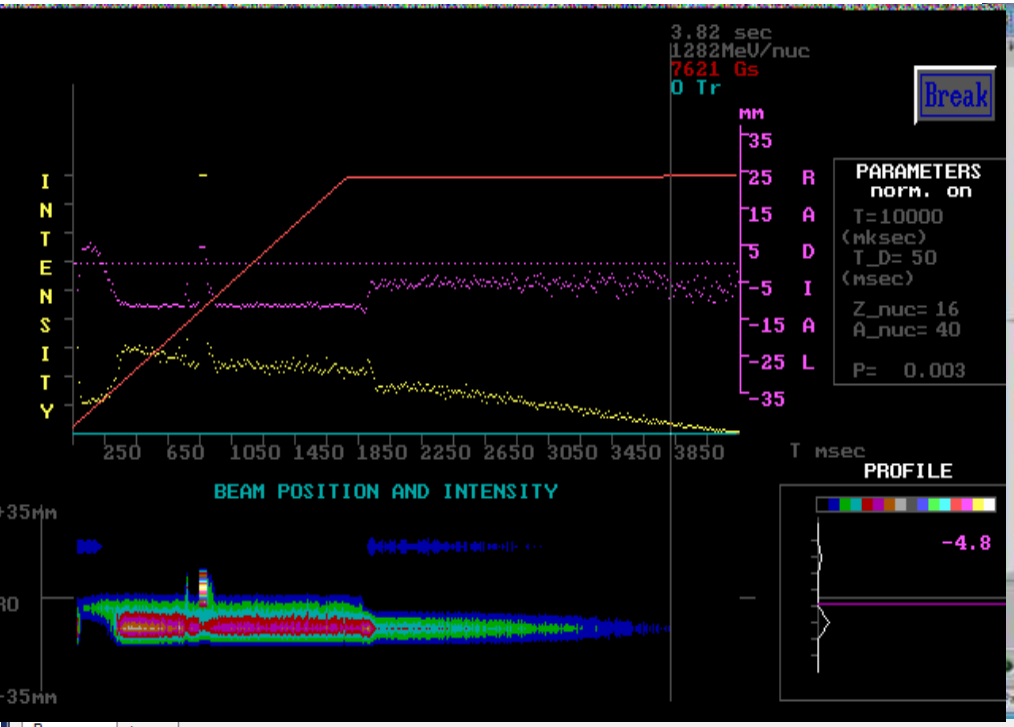
1 3 x 10^9 ppp Au^{31+} (or, alternatively Au^{51+});

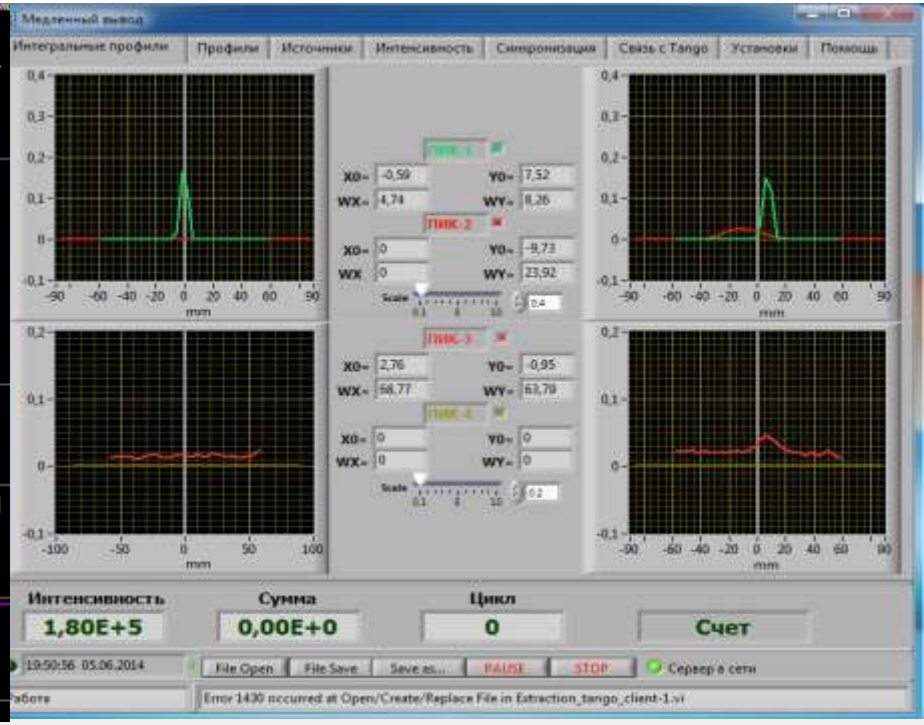
Ion beam extraction time from ESIS: 8 – 30 μs.

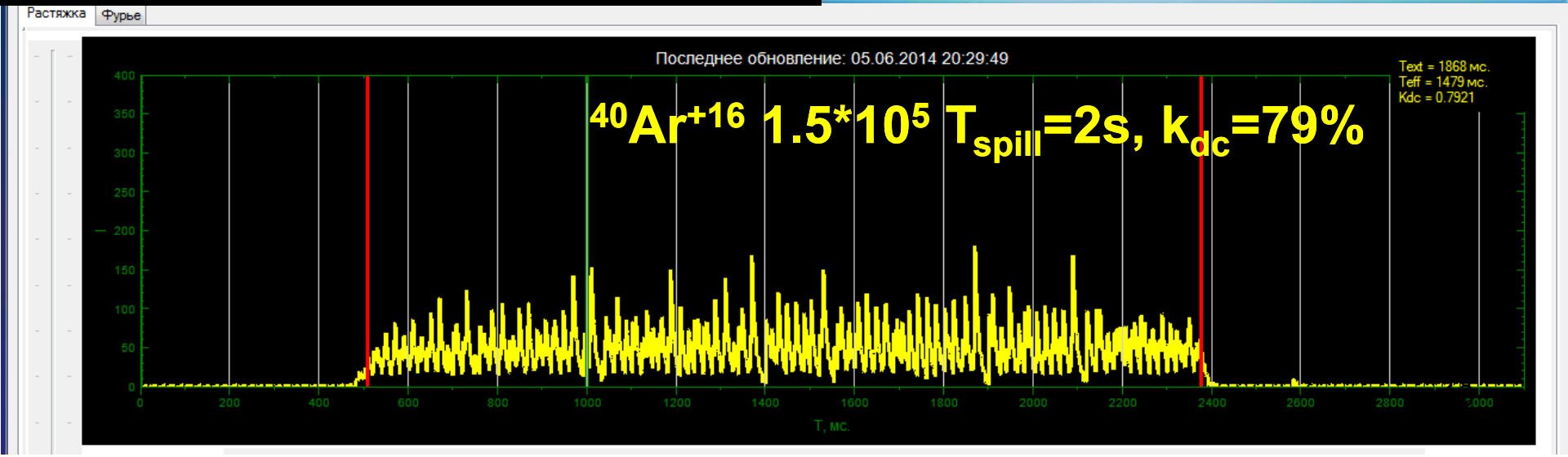
RMS emittance: 0.6 π mm mrad (extraction time 8 μs); 0.15 π mm mrad (30 μs).



$^{40}Ar^{+16}$ ions acceleration (1.2 Gev/u) RUN #50







Slow extraction development

Run #47:
Minimum spill duration ~ 60 ms
Discharge of ESS insulator during extraction at 5 GeV/u

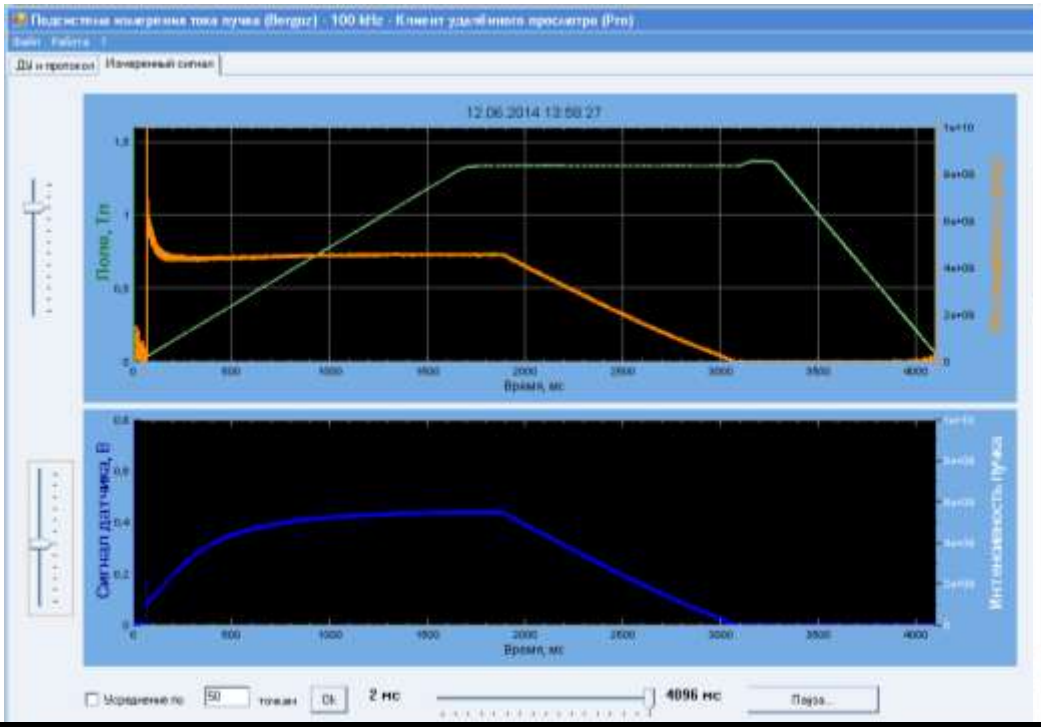
Run #48:
- Successive test of new power supply for slow extraction quadrupoles
- Demonstration of effective extraction at spill up to 20 s

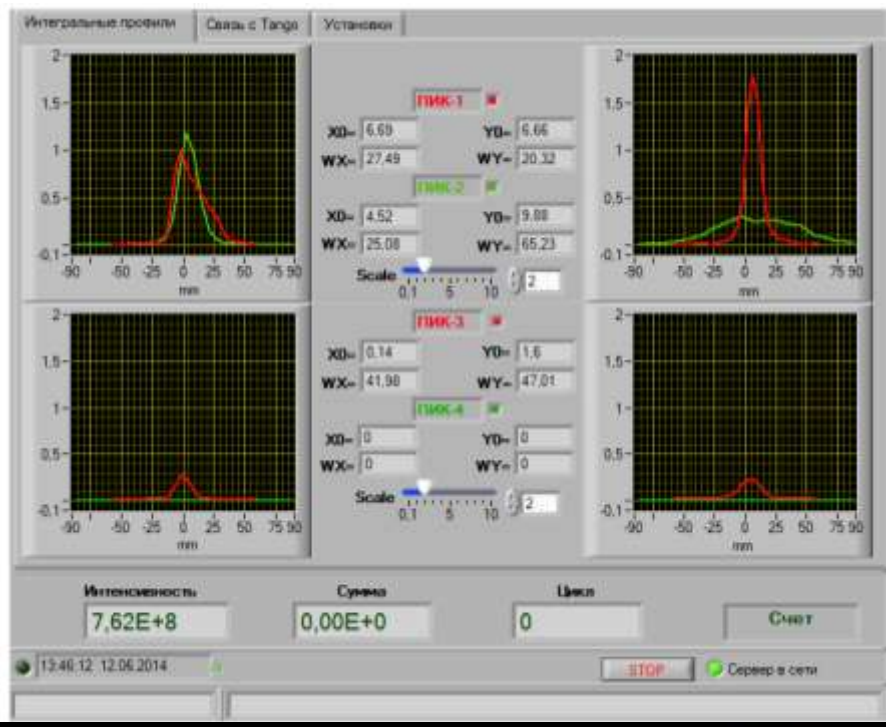
Run #49 – 50:
- Routine operation of new power supply for slow extraction lenses
-Good beam spill at low intensity

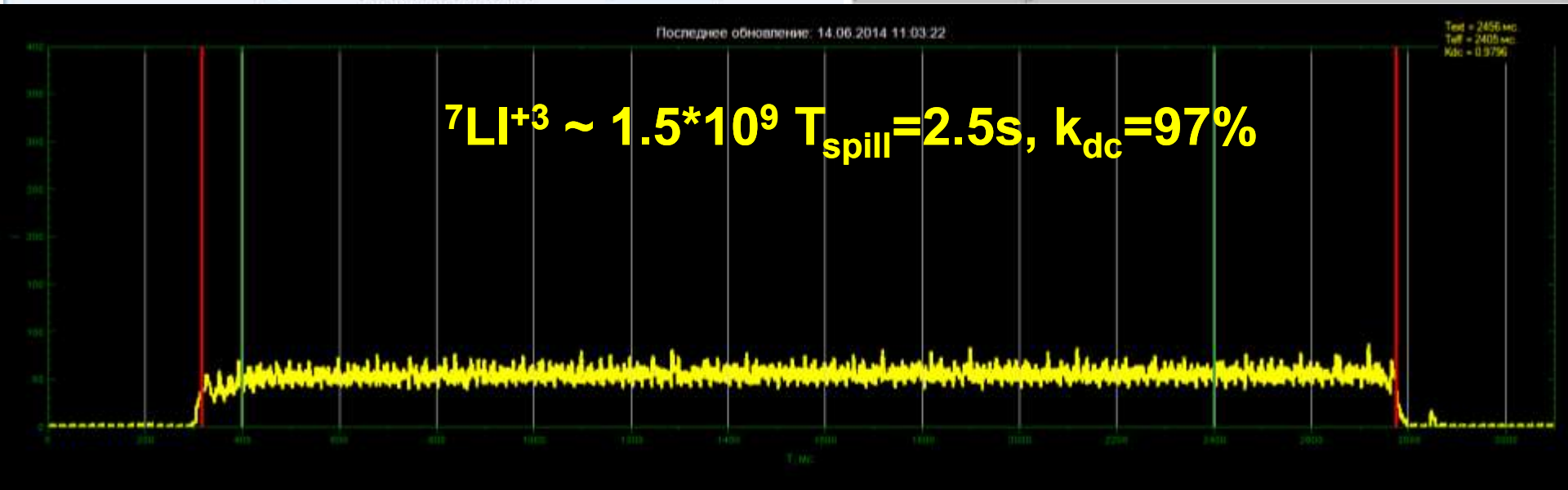
General problem:
ESS performance – **maximum achieved voltage is 110 kV**
(required at maximum energy – 200 kV)
Good quality at energy $\leq$ 3 GeV/u

Installation of new ESS is mandatory

$^{7}Li^{+3}$ beam acceleration (3 Gev/u) RUN #50







Machine development

-Beam diagnostics (Q-meter, beam loss monitor,)

-Power supply (current misbalance sources, slow extraction supply)

-Quench detection system

-Intensive test of equipment at large fields

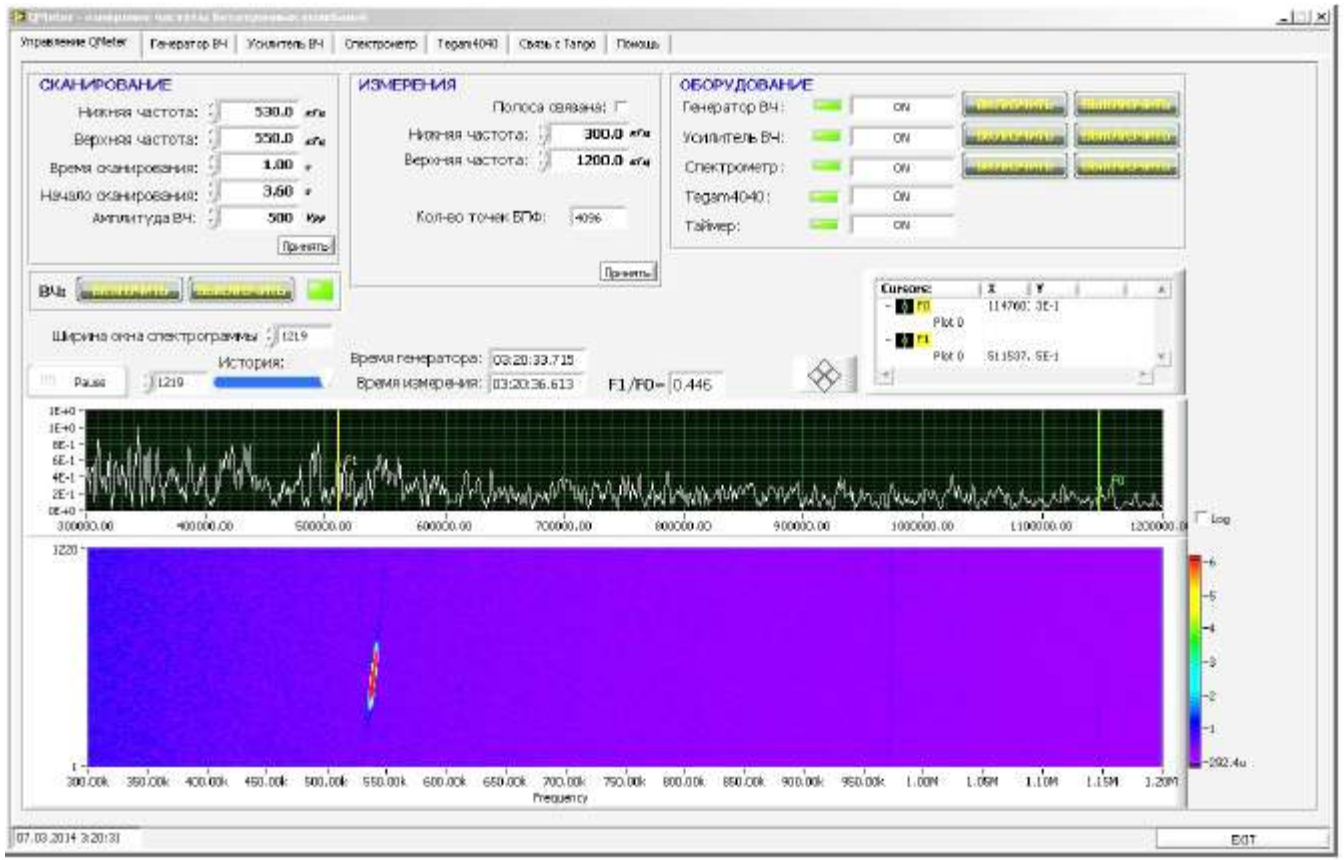
Q - meter


Генератор
Tektronix AFG 3102
Усилитель
AR 800A3A
Трансформаторы 1 , 2
AR IT2002
Переключатель X/Z
Киперы X , Z
Старт
Начало цикла
Дигитайзер
Таймер
PXI National Instruments
Старт
Анализатор спектра
Agilent N9340B
Пикап - электроды X , Z
Переключатель X/Z

Q - meter

Q - meter

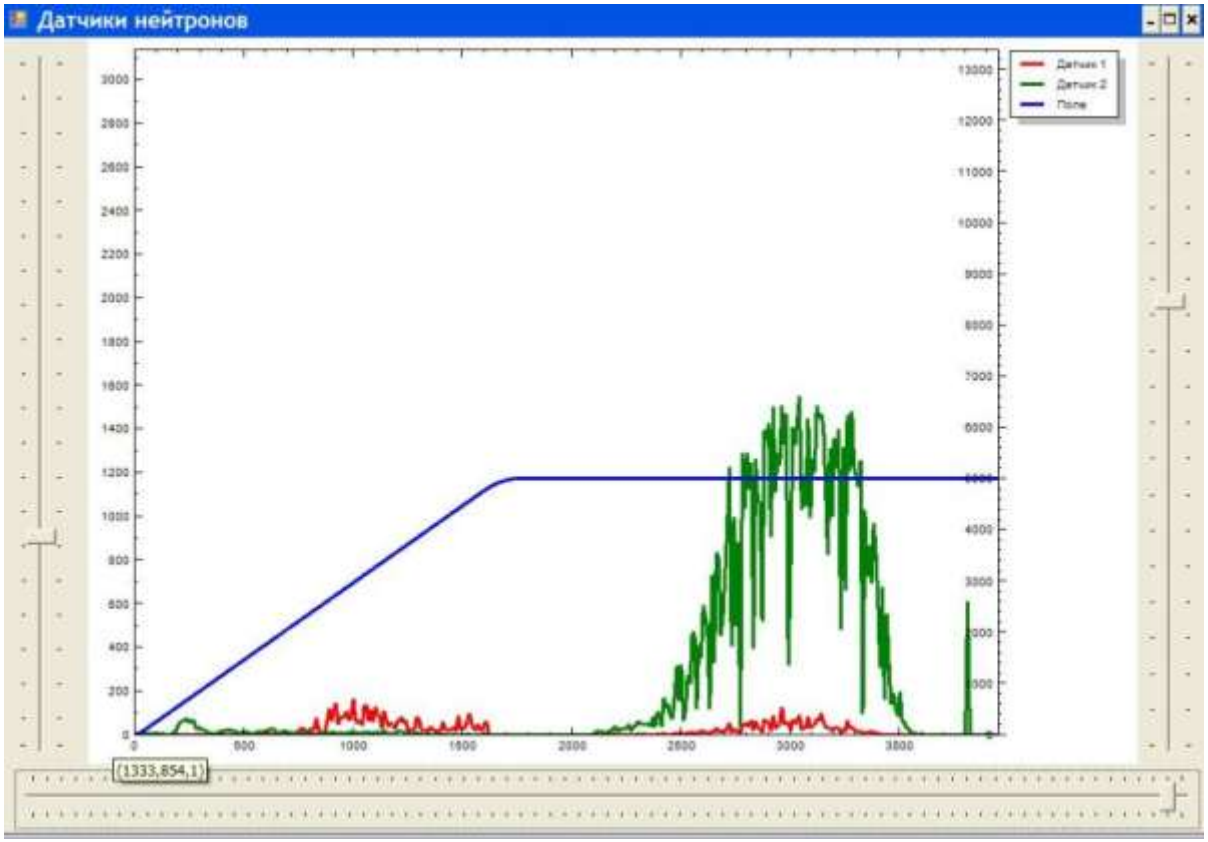
Client application for Tango



Beam loss monitor system

Particle losses during acceleration and extraction (run #46)

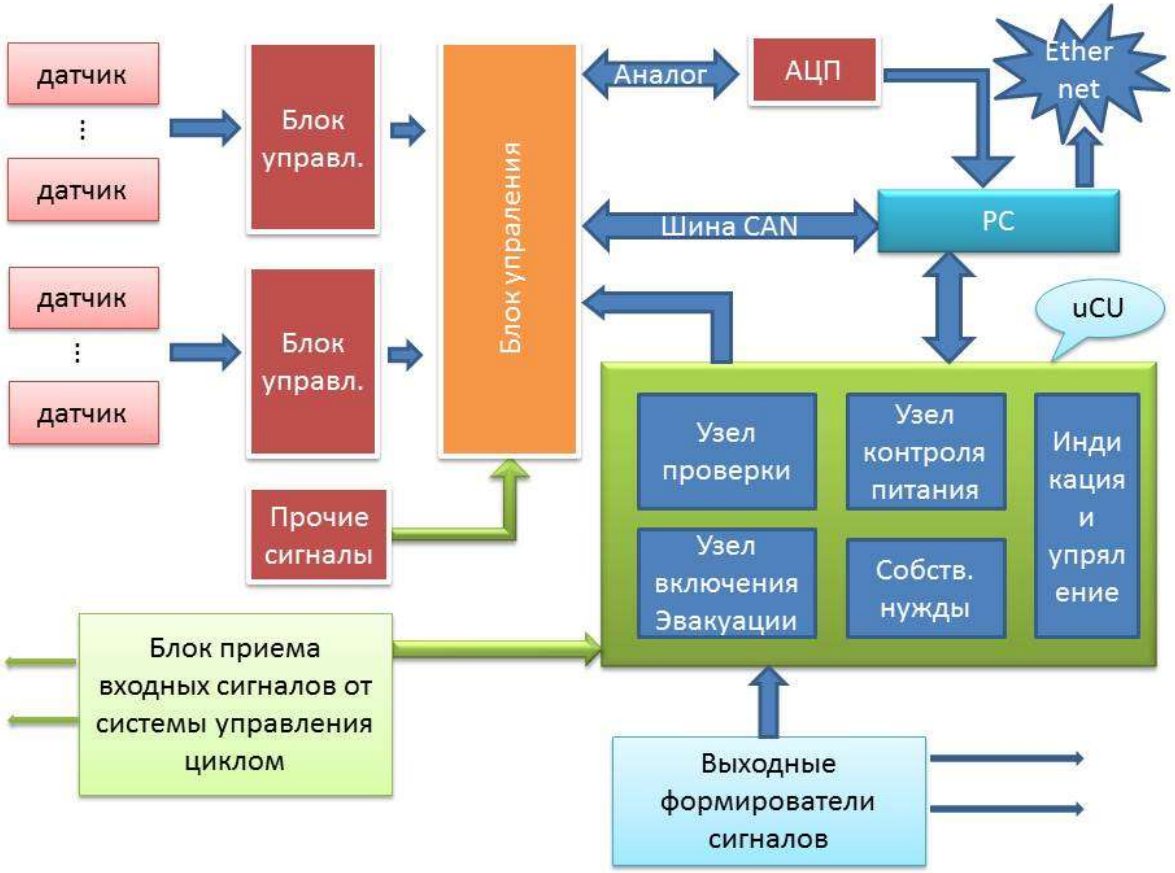
Детектор нейтронов
БДКН-96



Now – 4 detectors

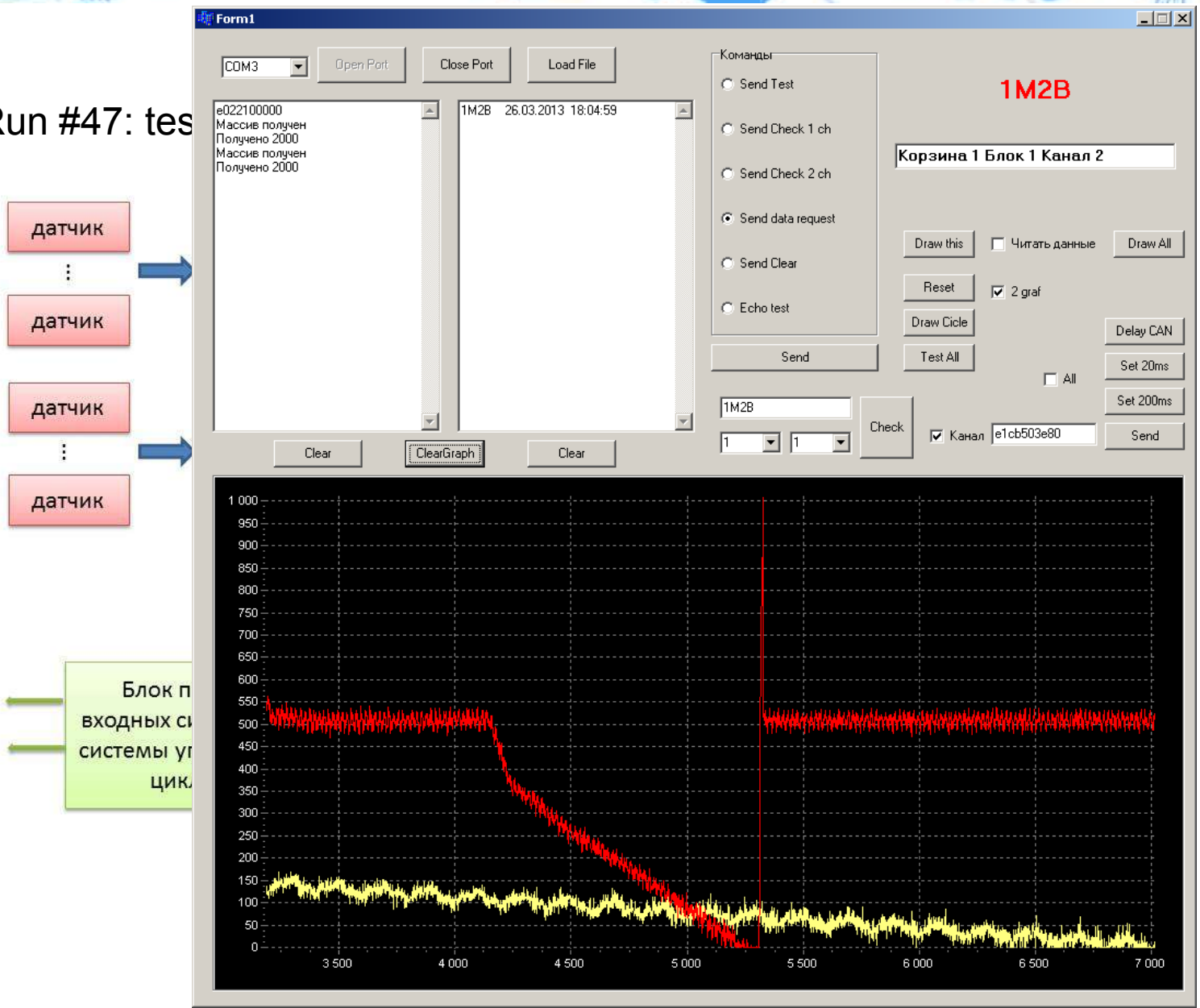
Control system for quench detectors

Run #47: test version of the quench detector control system



Control system for quench detectors

Run #47: tes



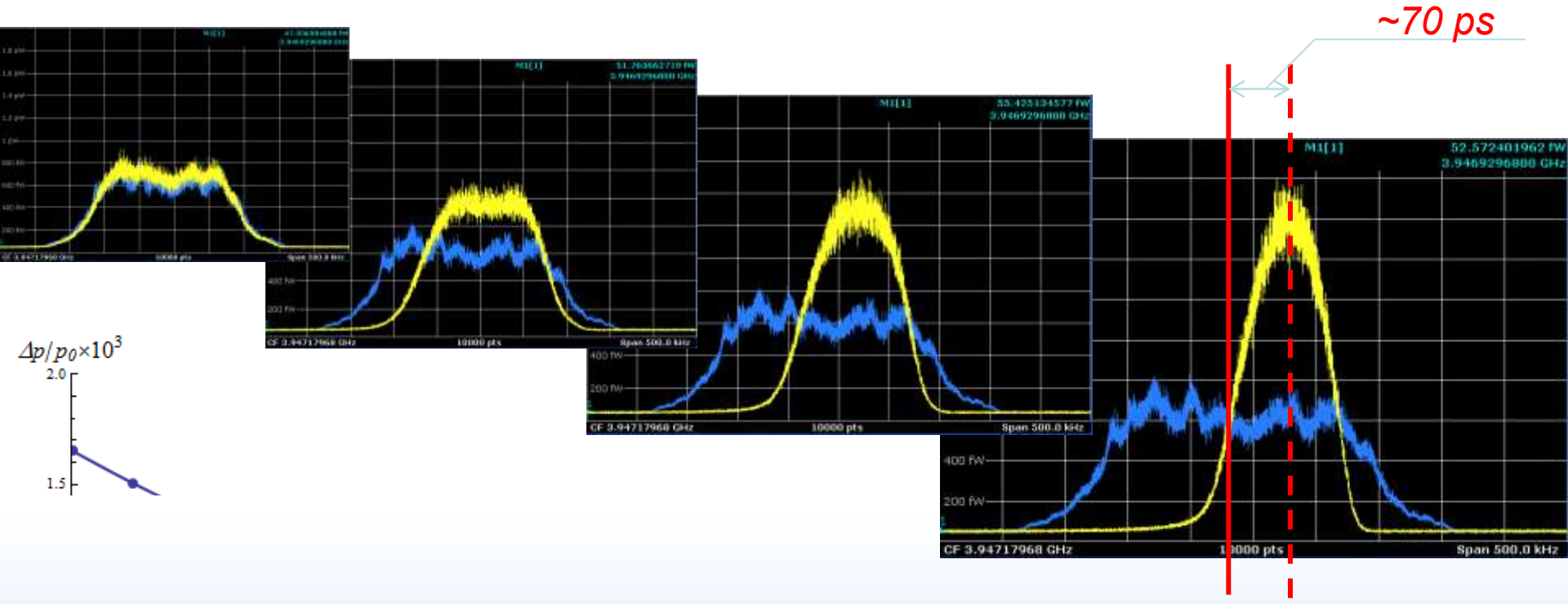
R&D for NICA

-Control system based on TANGO

-Stochastic cooling

Stochastic cooling, run #47

Longitudinal cooling, filter method, coasting D-beam, P = 20 W



- E[htriment duration: *480 s*
- dp/p (1e-3): *1.65 -> 0.56*
- τ0 ~*365c*

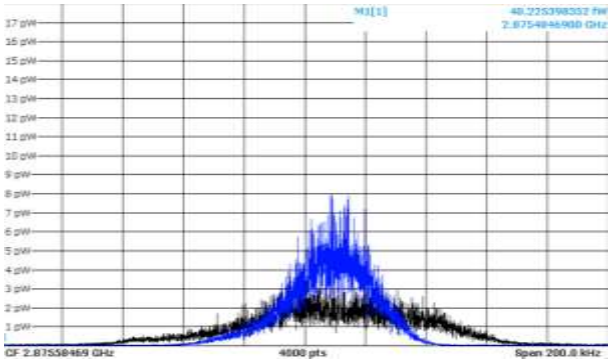
Stochastic cooling of the carbon beam 2.5 GeV/u

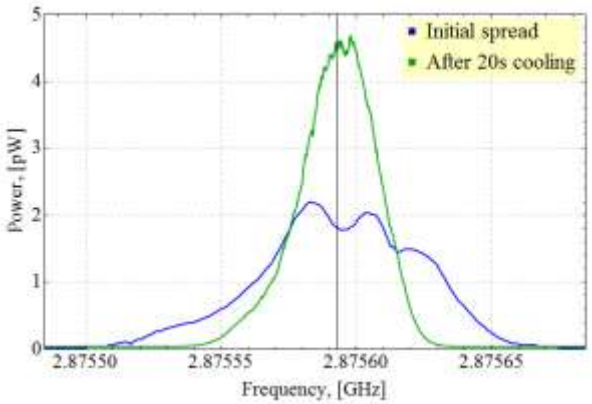
Run #48

Spectrum analyzer

Computer reconstruction

Coasting beam



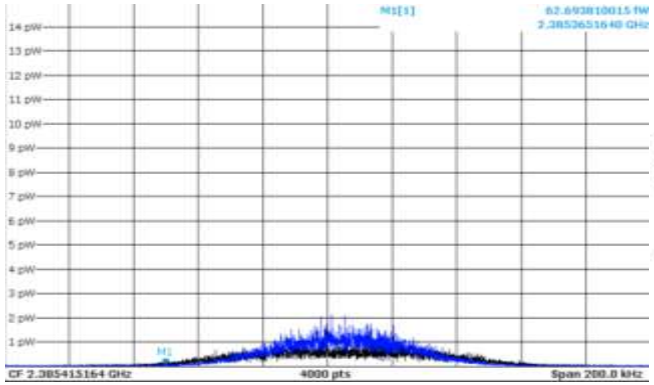


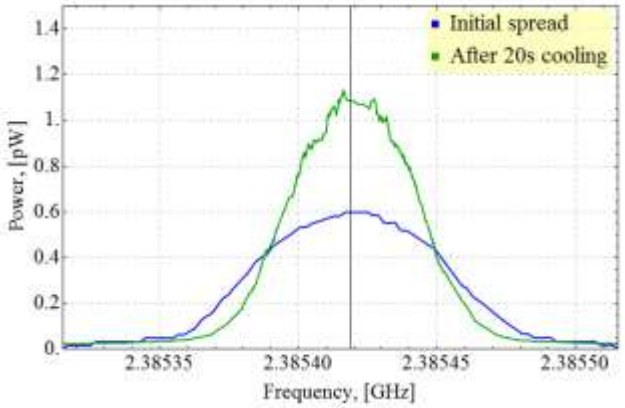
$\sigma_{...it} =).15 \times 0^{-}$

$\sigma_{.nal} =).07 \times 0^{-}$

$\tau \approx ?7s$

Bunched beam





$\sigma_{...it} =).2 \times 0^{-}$

$\sigma_{.nal} =).13 \times 0^{-}$

$\tau \approx 49s$

σ_s = 4.2 m

RF voltage of 2 kV at plateau duration up to 25 sec,
bunching factor (peak/mean current) ~ 5 (for NICA ~ 15)

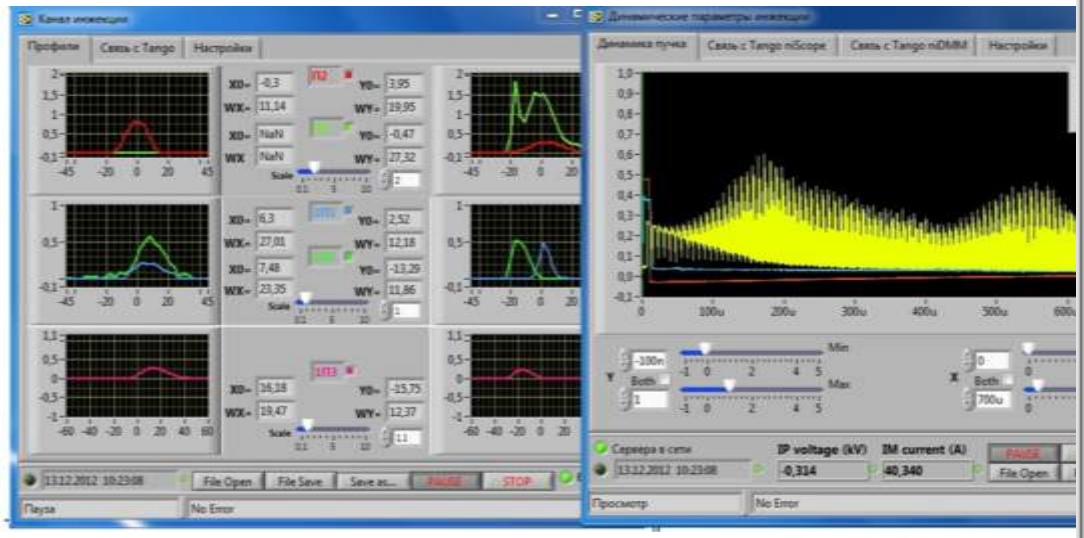
New control system

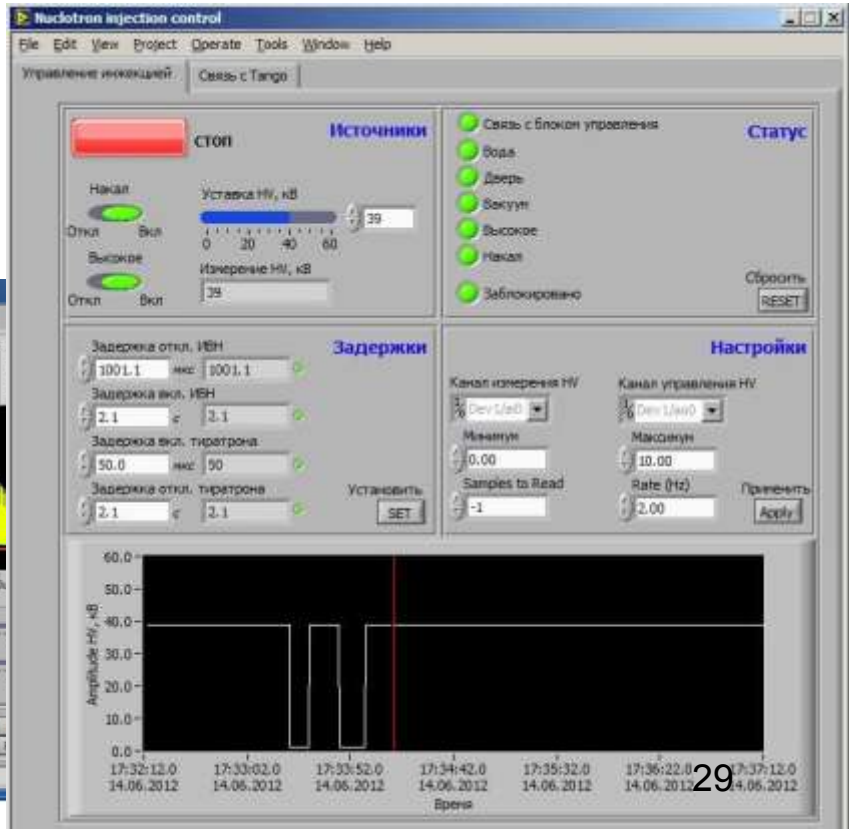
In June 2012 NICA machine advisory committee recommended to test **TANGO** as a NICA control system

•Modern object oriented distributed control system based on CORBA. Developed as a collaborative effort between the Alba, Desy, Elettra, ESRF, FRM II, MAX-lab and Soleil.

Experimental fragment was tested In 2012. Now:

- **injection control;**
- **control of the inflector plates;**
- **diagnostics and controle of slow extraction**
- **….**





Status of the Nuclotron

Parameter	Project	Status (June 2014)
Max. magn. field, T	2	2 (1.8 T routine)
B-field ramp, T/s	1	0.8
Accelerated particles	p–U, d↑	p–Xe,
Max. energy, GeV/u	12 (p), 5.8 (d) 4.5($^{197}Au^{79+}$)	5.8 (d, ^{12}C), 1.5 ($^{124}Xe^{42+}$, $^{40}Ar^{16+}$) Slow extraction sys upgrade is needed
Intensity, ions/cycle	1E11(p,d), 2E9 (A > 100)	d $5*10^{10}$ ($2*10^{10}$ routine), $^{124}Xe^{24+}$ $1*10^{4}$ ^{12}C $2*10^{9}$ $^{40}Ar^{18+}$ $2*10^{5}$ $^{7}Li^{3+}$ $3*10^{9}$

Thank you for attention