INSTITUTE FOR HIGH ENERGY PHYSICS (IHEP)
Protvino, Moscow Region, 142281, Russia

Accelerator Complex U70 of IHEP: Status and Upgrades

(invited oral WEYCH01)

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XXIII Russian Particle Accelerator Conference

RuPAC-2012

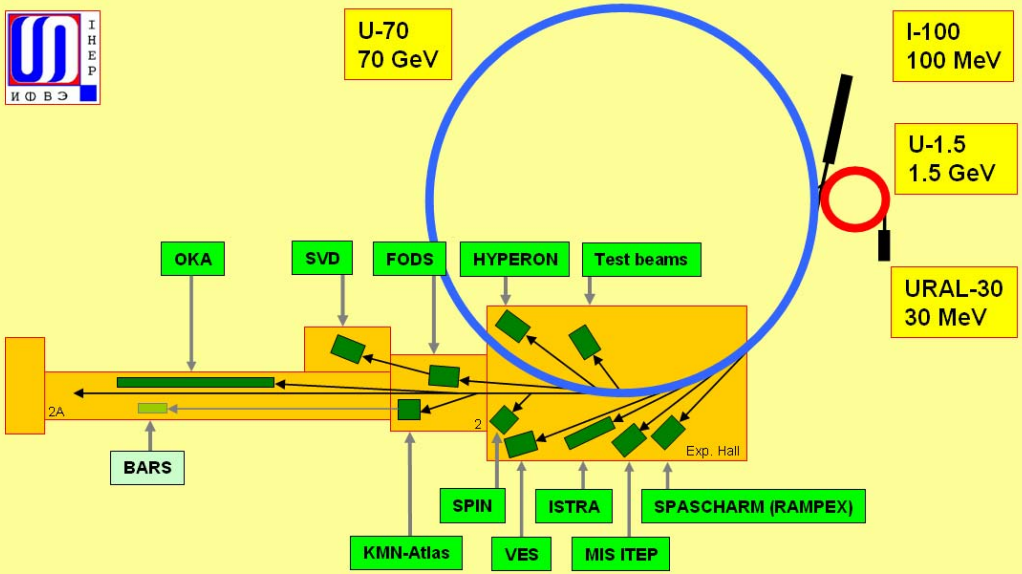
September 24-28, 2012, St-Petersburg, Russia

Outlook

- Generalities
- Routine operation
- Machine development
- Light-ion program (+ elsewhere, oral rep. WECCH01)
- Conclusion

Emphasis on a progress since RuPAC-2010

Layout



4 machines (since Oct 2007):
- 2 linacs
- 2 synchrotrons

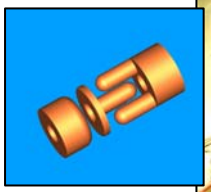
Modes:
- proton (default) URAL30-U1.5-U70
- light-ion (*d*, C) I100(2 of 3)-U1.5-U70

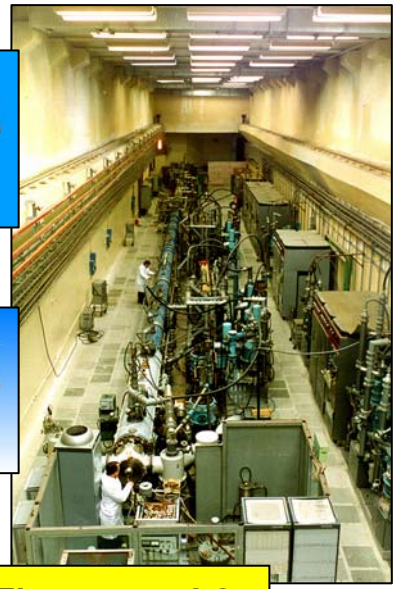
to note: OKA (#21), FODS (#22), stretcher (#25)

Light-ion:
- high energy 24.1-34.1 GeV/u
- intermediate energy 453-455 MeV/u

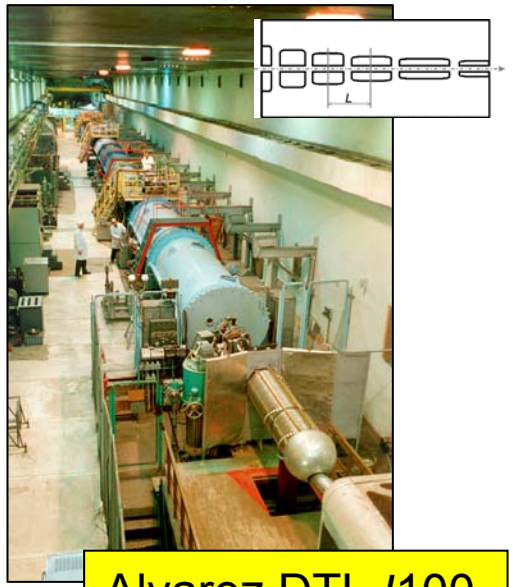
In a SIS-18, SIS-100 name convention:
- LIS-233 [T·m]
- LIS-6.9 [T·m]

Photo album of machines

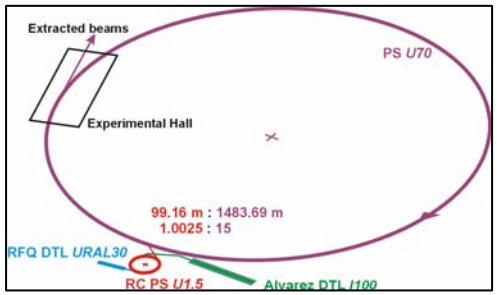




RFQ DTL *URAL*30



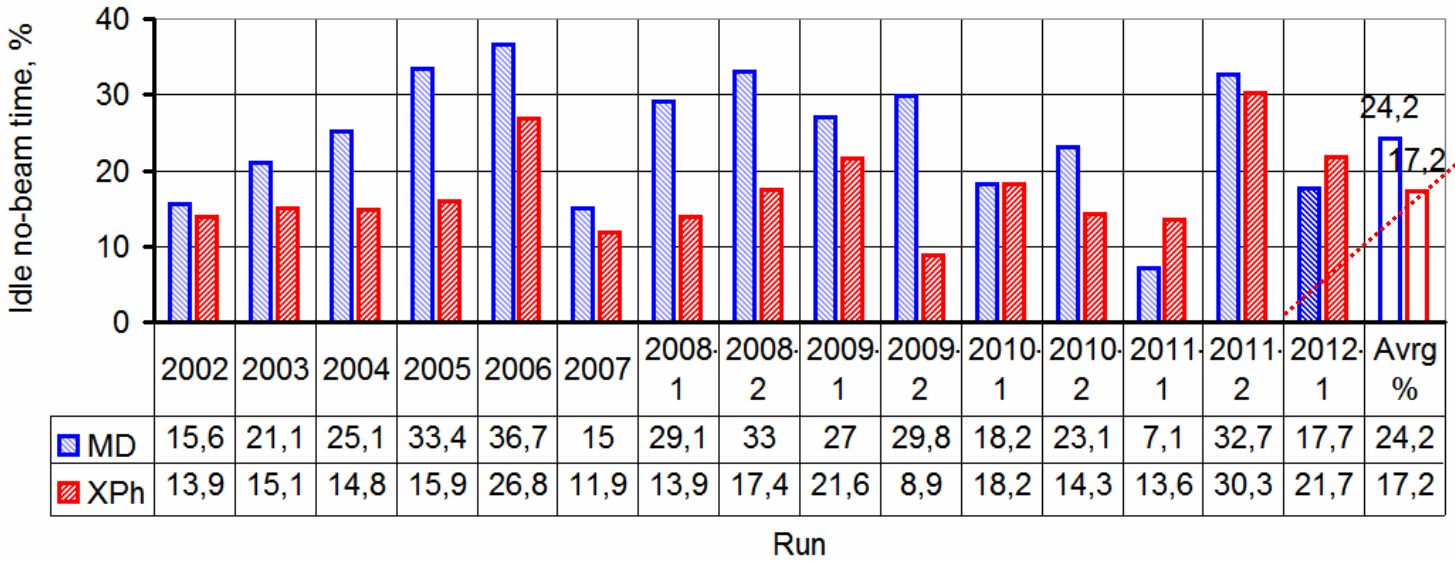
Alvarez DTL *I*100



RC PS *U*1.5

Main PS *U*70

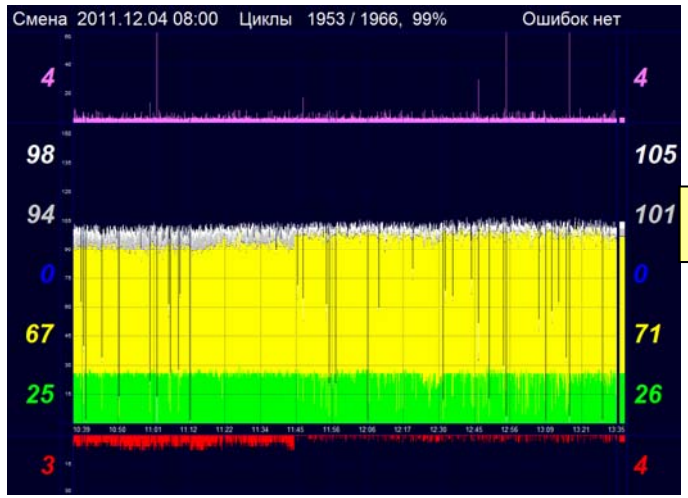
Statistics



	2002	2003	2004	2005	2006	2007	2008-1	2008-2	2009-1	2009-2	2010-1	2010-2	2011-1	2011-2	2012-1	Avrg %
MD	15,6	21,1	25,1	33,4	36,7	15	29,1	33	27	29,8	18,2	23,1	7,1	32,7	17,7	24,2
XPh	13,9	15,1	14,8	15,9	26,8	11,9	13,9	17,4	21,6	8,9	18,2	14,3	13,6	30,3	21,7	17,2

2012-1	Avrg %
17,7	24,2
21,7	17,2

2 runs (7/24) per year:
- short (XPh 10 days ca) 2 MD(*p*) + ions
- long (XPh 30 days ca) 3 MD(*p*) + ions

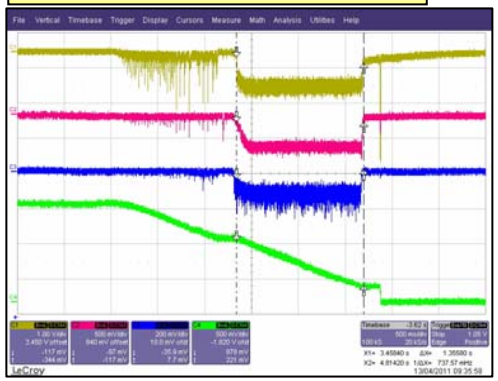


$1 \cdot 10^{13}$ ppp

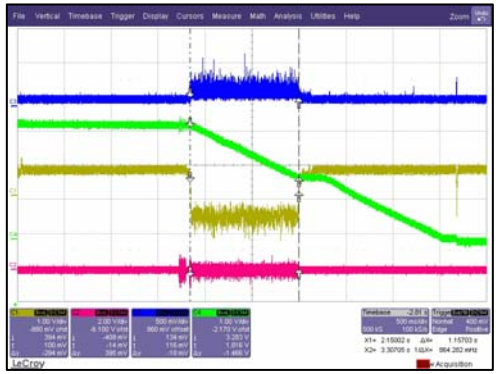
3 hr, 1000 cycles

Extraction (fixed target)

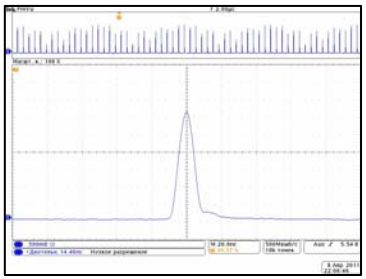
2nd ½ of flattop, IT & CD

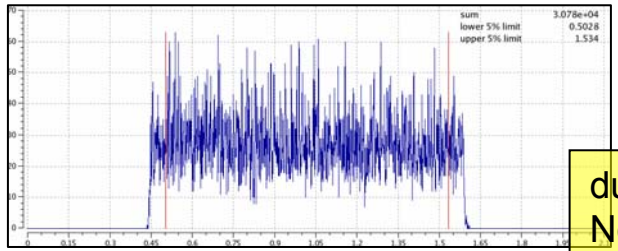


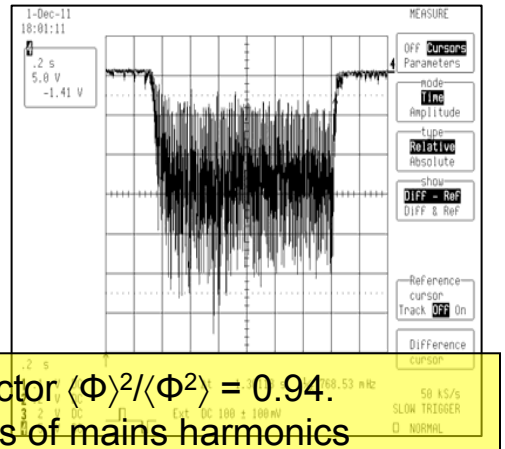
1st ½ of flattop, SSE



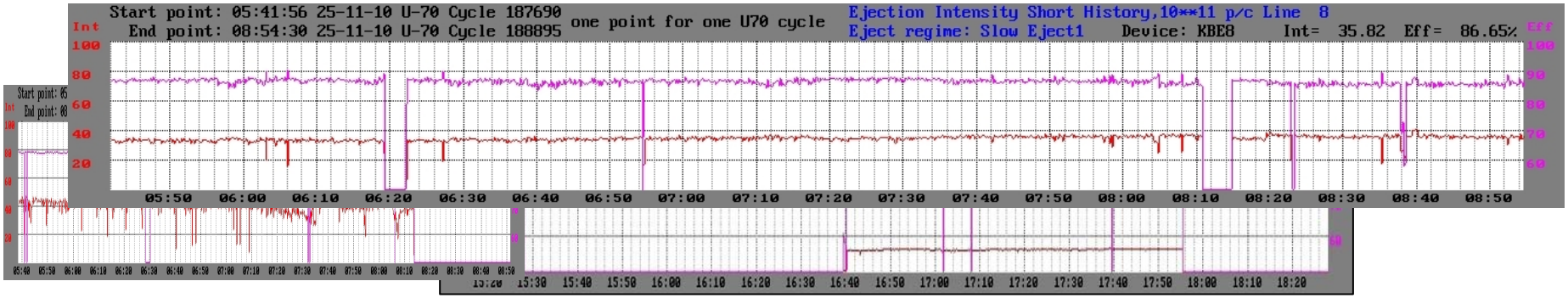
Inventory:
- 1-turn FE
- SRE (Q38 & SSE)
- IT
- Si-CD SE
- flat-bottom (S)SE







duty factor $\langle\Phi\rangle^2/\langle\Phi^2\rangle = 0.94$.
No lines of mains harmonics



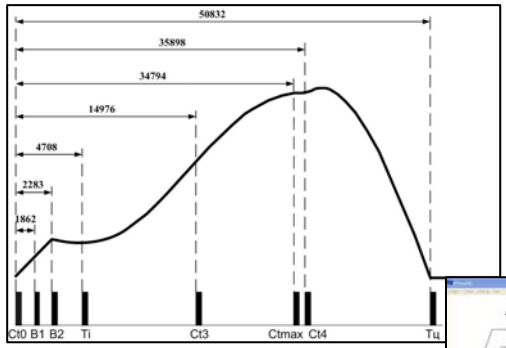
Machine development

4 machines:
- Planned maintenance
- Emergency maintenance
- Development (*p*- and *i*-modes)

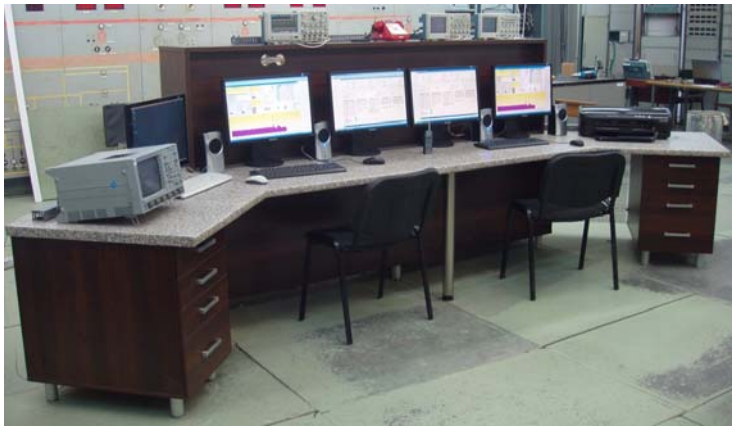
Machine development (1)

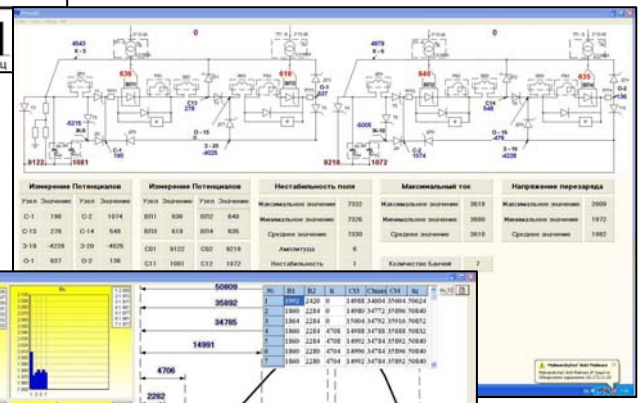
new Local Control Center for U1.5 ring magnet PS

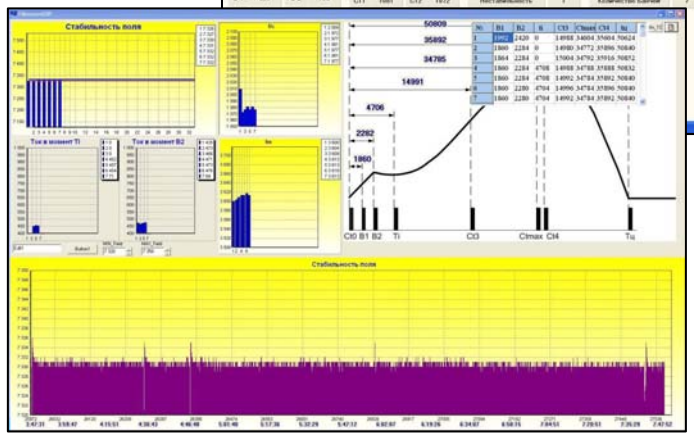
10 kV, 6 halls в 5 buildings, external 2 transformer stations, 3 switchovers



16 2/3 Hz





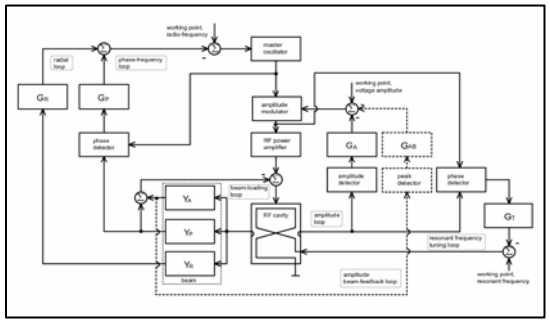


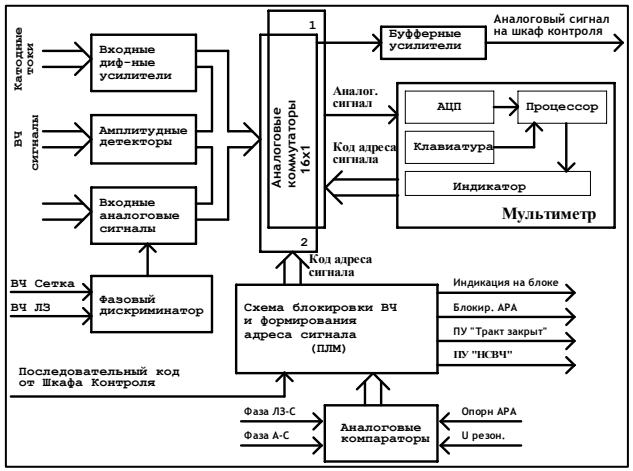
Machine development (2)

new Control (amplitude, phase) and Interlock System for the U70 RF accelerating system

40 ferrite loaded RF cavities:

- 2010 – 20 cavities
- 2011 – 10 , 30 of 40 in total





Machine development (3)

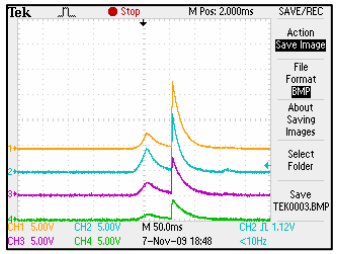
Beam Loss Monitoring System in the U70

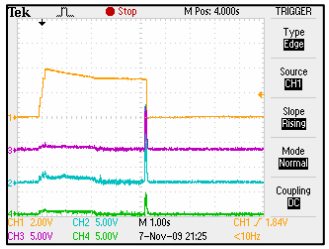
Plan = 120 = No. of CF magnets

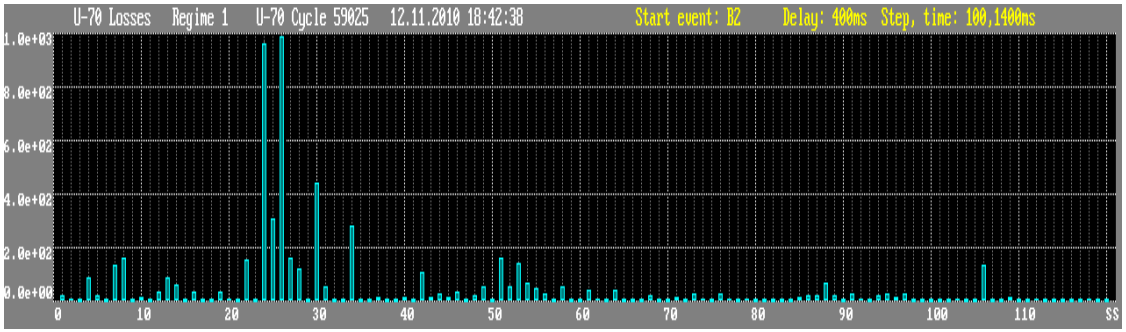
2010 – 4 test channels

2011 – 30 operational channels

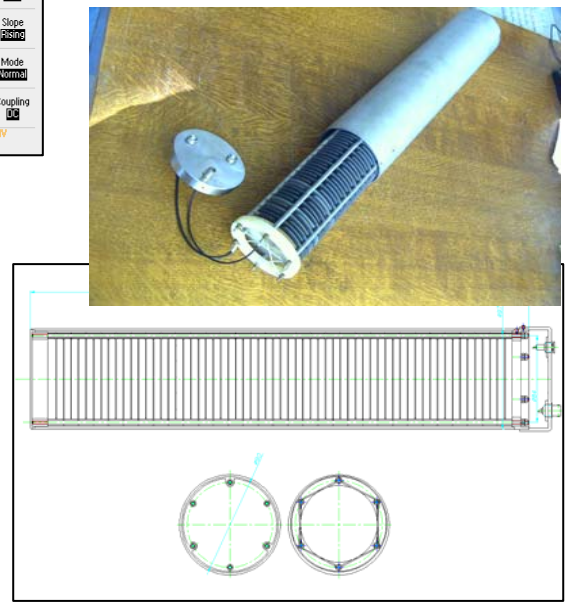
Soft- and hard-ware complex (32-channel counters with control programs)





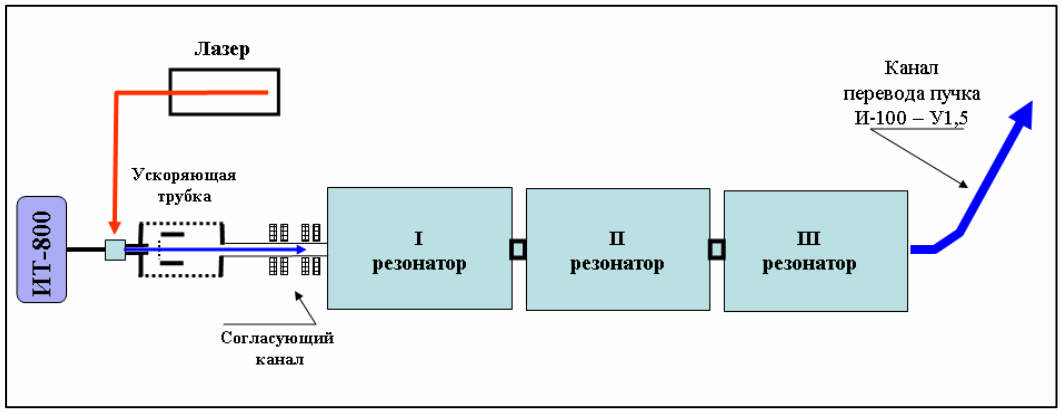


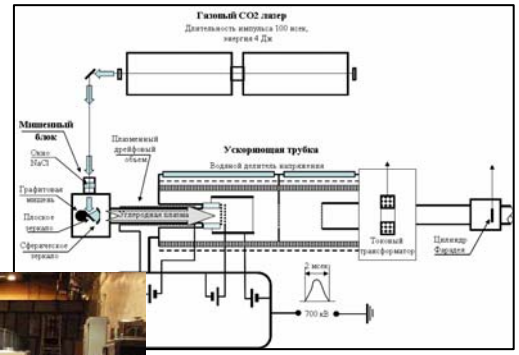
SS# 22-34, 42-57, 106

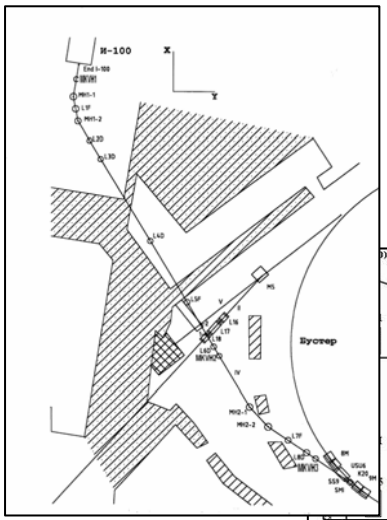


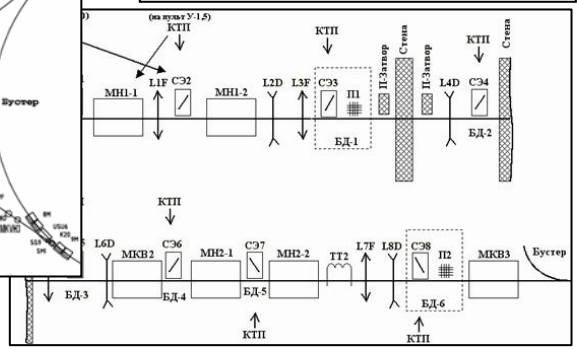
Machine development (4)

Stand-alone runs of I100



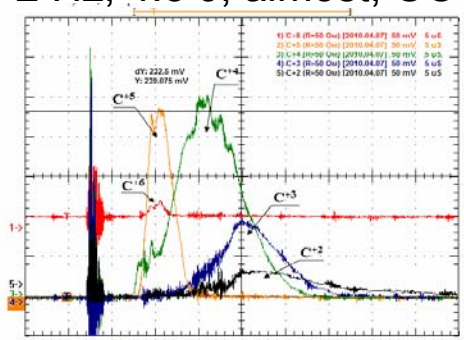






43 m long
4 dipoles
8 quads
3 H/V-correctors
Beam diagnostics

InfraLight SP, PhIC GPhI RAS, Troitsk
2 modules, CO2, N2 и He, λ=9.6–11 μm
2 Hz, 4.5 J, almost, COTS



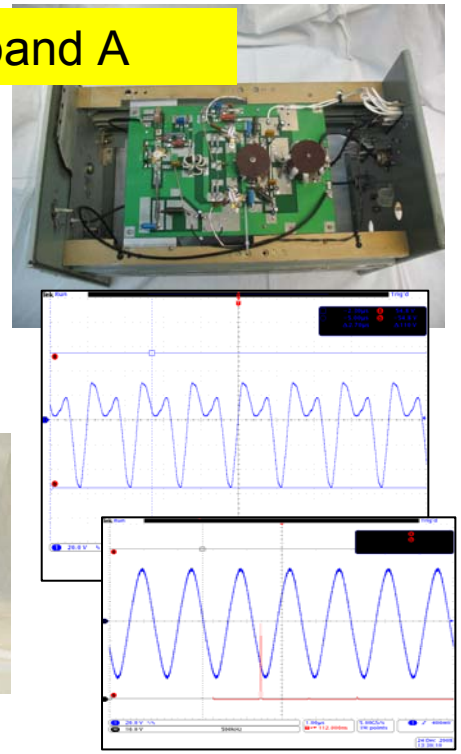
10–12 mA 4000 cycles
(former 800), i.e. >8 hr.

Machine development (5)

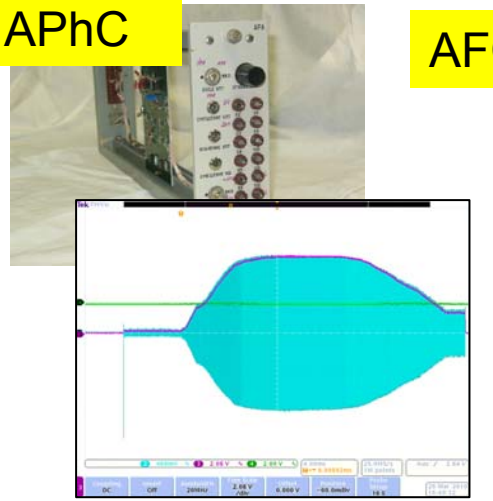
Upgrade of RC PS U1.5 RF sustem

V	0.1-10 kV
f_{RF}	0.75-2.8 and 0.56-2.3 MHz
df_{RF}/dt	170 and 110 MHz/s
T	60 ms
P_{RF}	60 kW
P	130 kV A

wide-band A



APhC

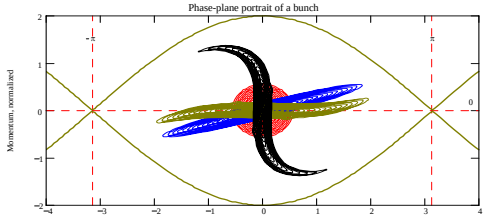


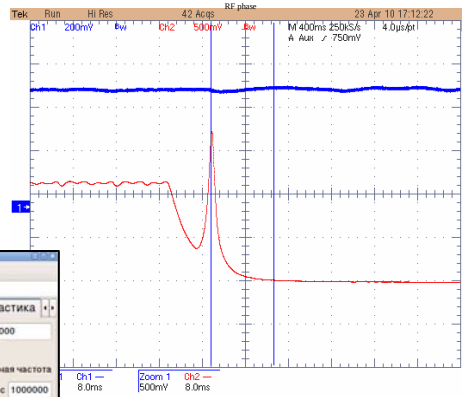
AFC

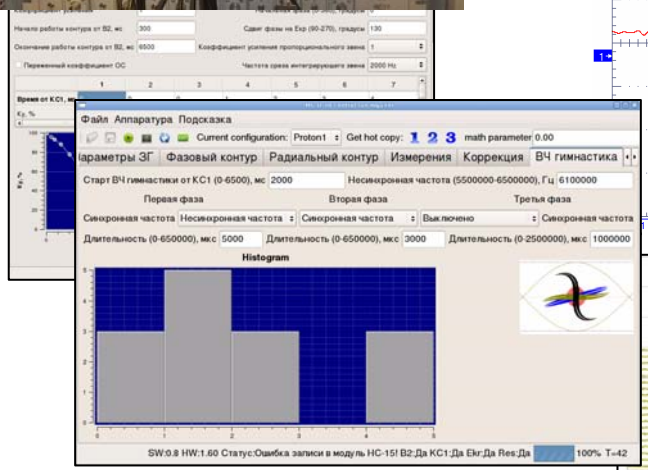
Dynamic range	× 15
Transient time	× 1/5
Overshoot	× 1/10

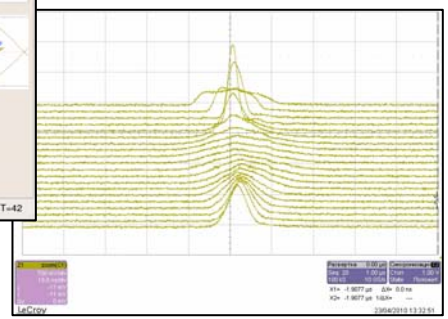
Machine development (6)

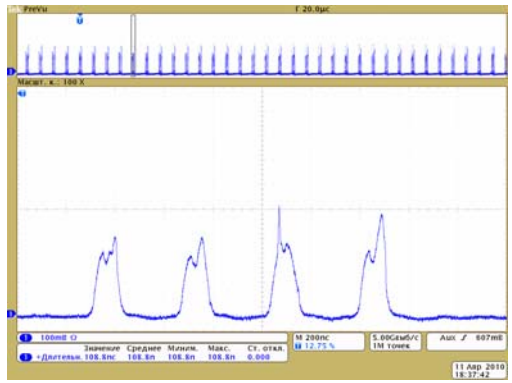
New digital MO in RF of the U70

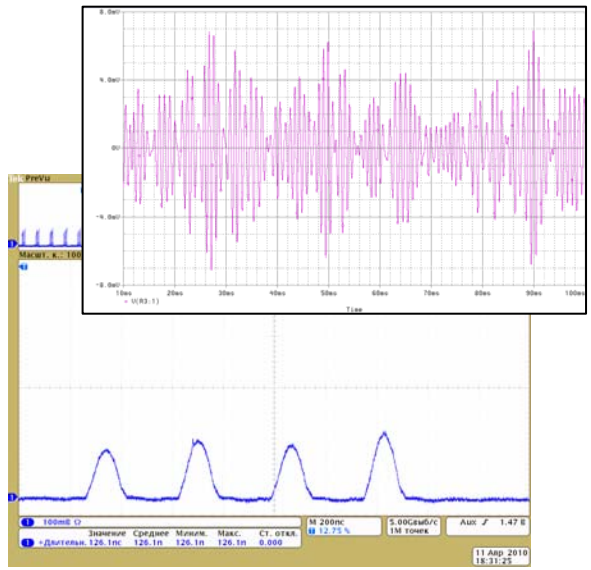




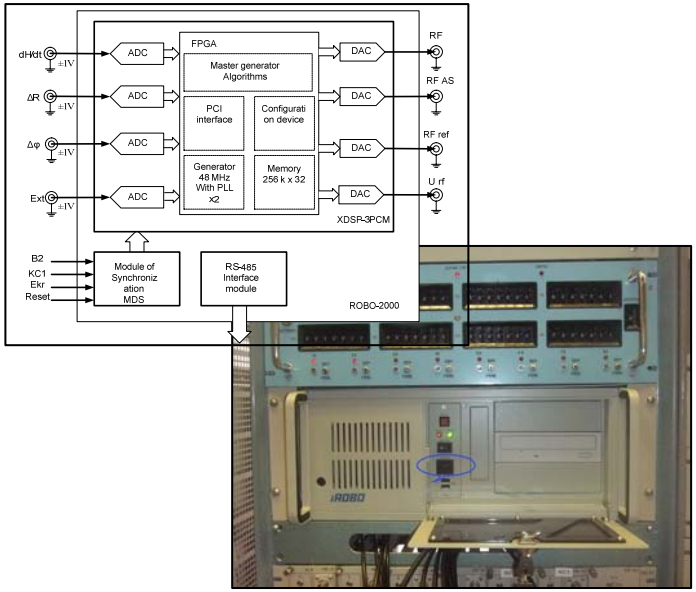


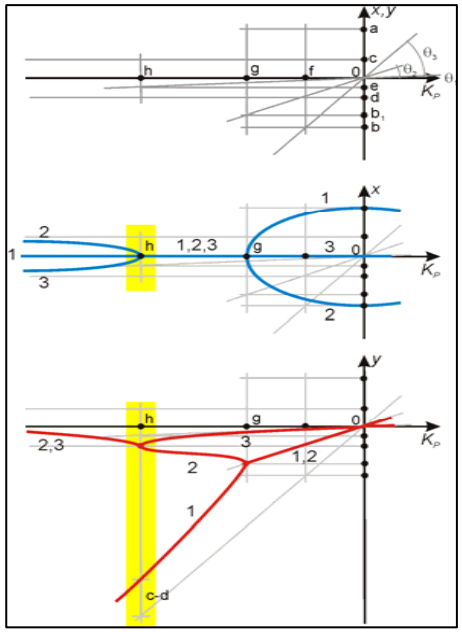


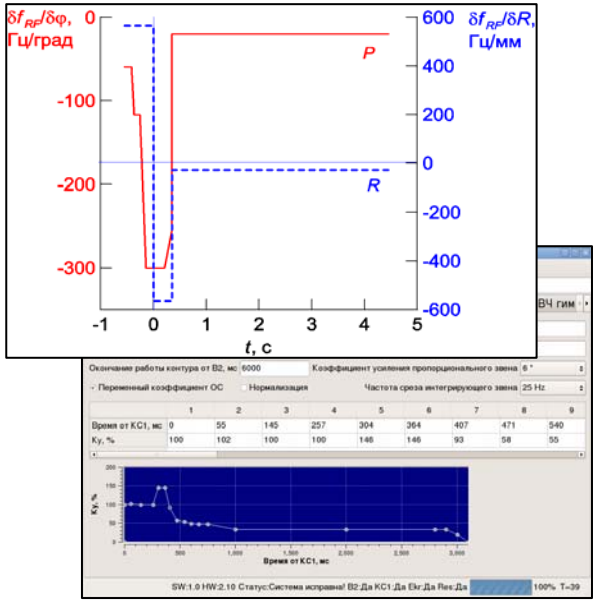


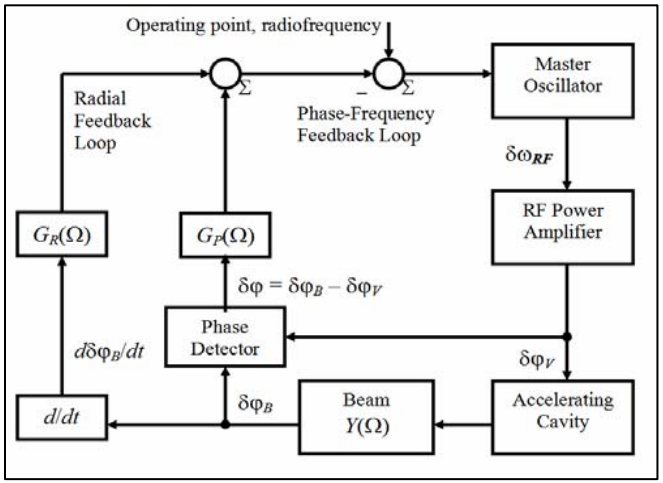


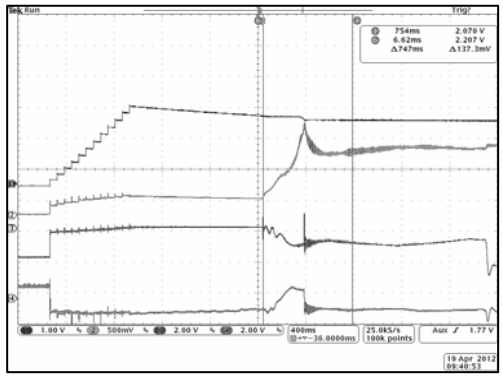
DDS RF MO and Fbcks

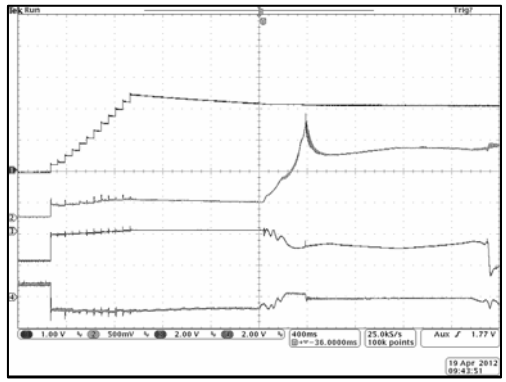




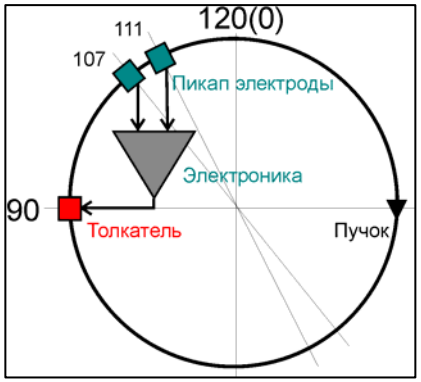


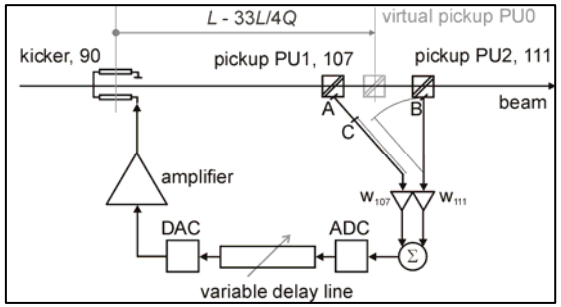


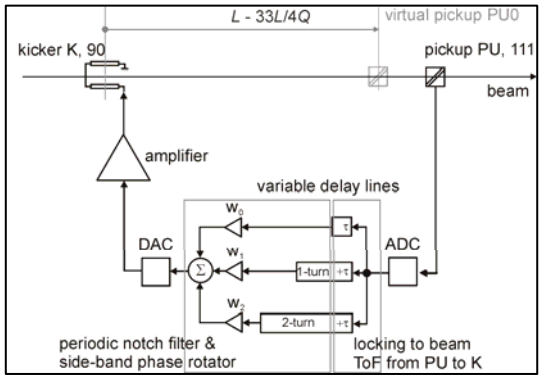


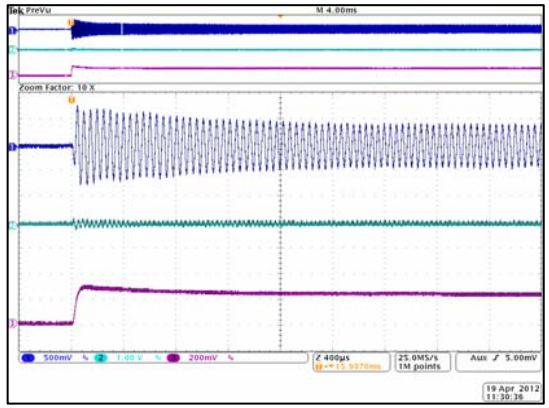


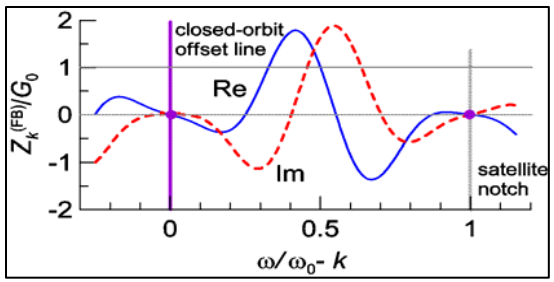
Digital transverse Fbck

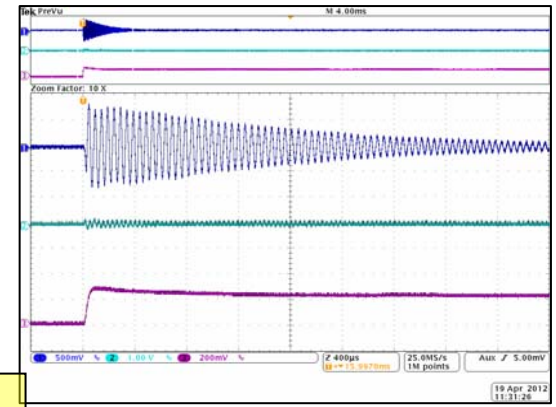


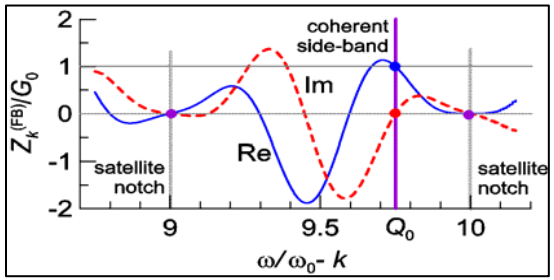


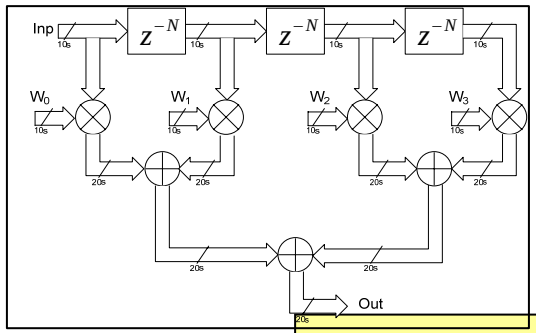












FIR-3 & FIR-4 options

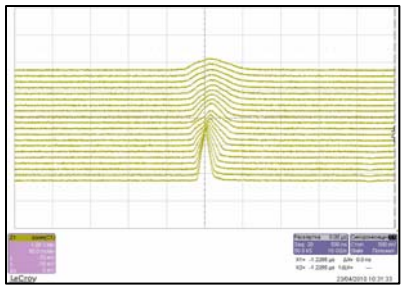
Instabilities

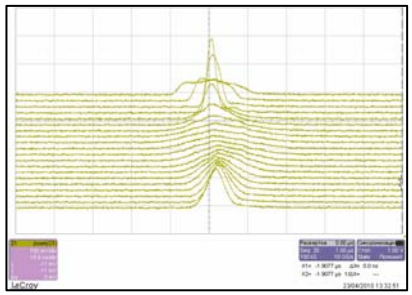
Back to factory default freq range of RF system, 2.6 (4.5)-6.1 MHz instead of o 5.5-6.1 MHz

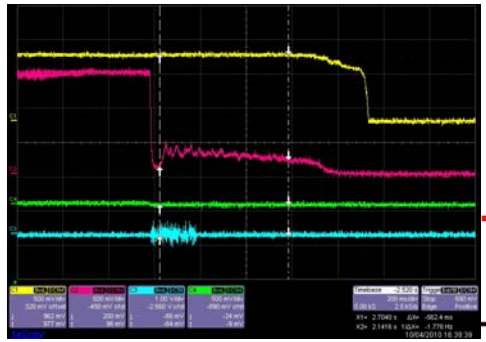
$$\left|\frac{Z(k\omega_0)}{k}\right| < \frac{1}{\Lambda}\frac{\beta^2|\eta|E}{eJ_0}\left(\frac{\Delta p}{p}\right)^2$$

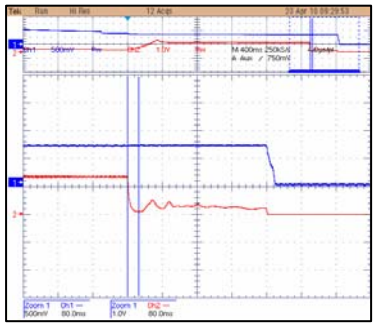
Cures:

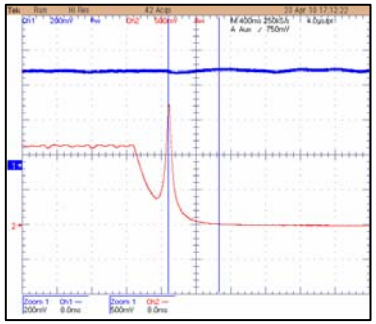
- momentum spread, RF gymnastics
- Distribution function [momentum spread] RF noise

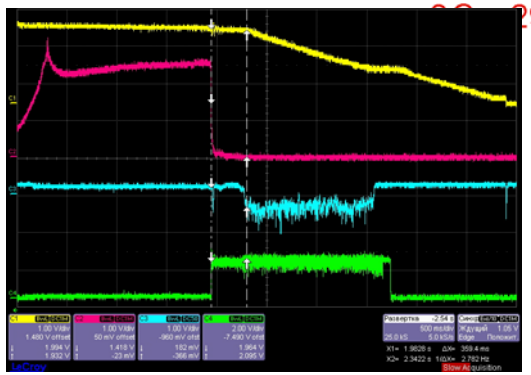


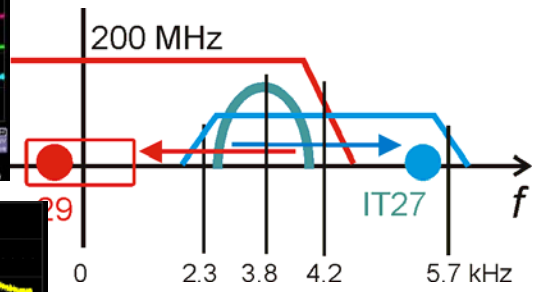








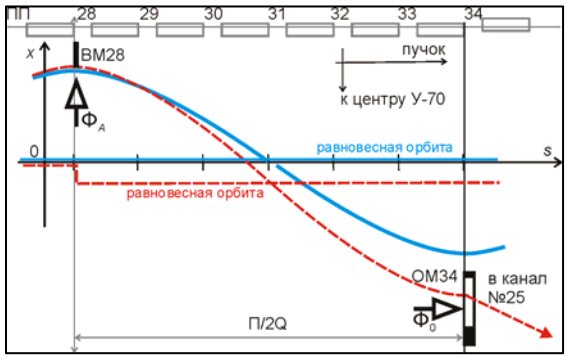


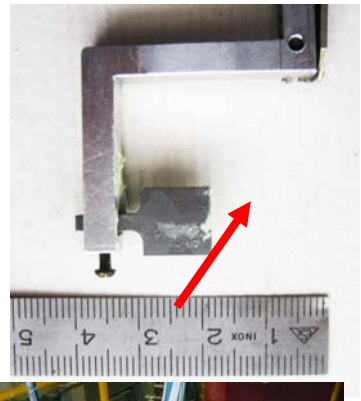


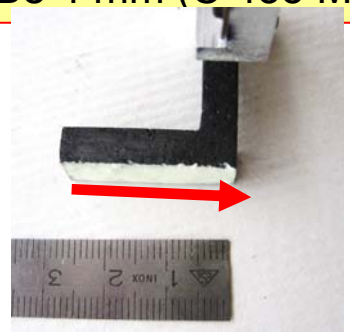
Flat-bottom S(S)E

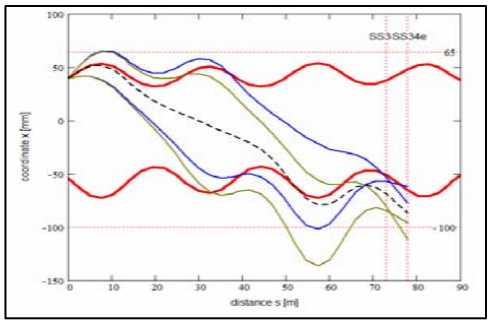
352 Gs, 1.32 GeV (p, test beam) 455 MeV/u (C)

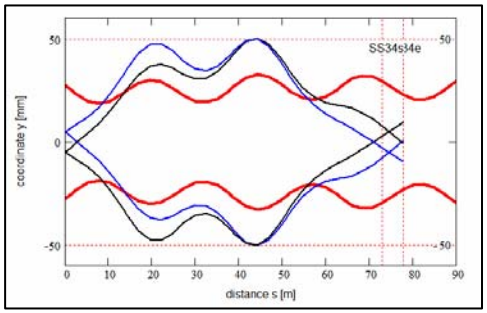
Graphite 30 mm (*p* 1.32 GeV)
Be 4 mm (C 455 MeV/u)

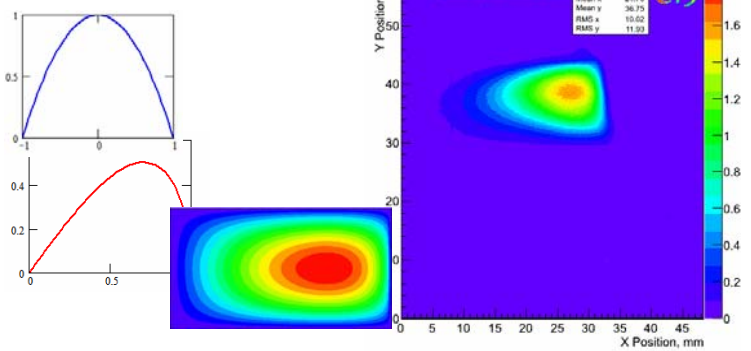


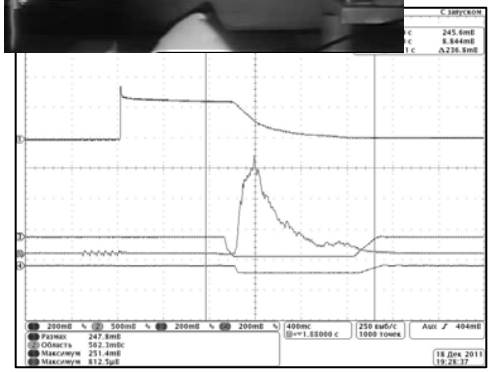






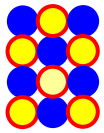






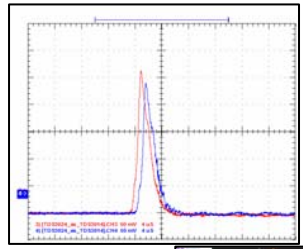
Ion program

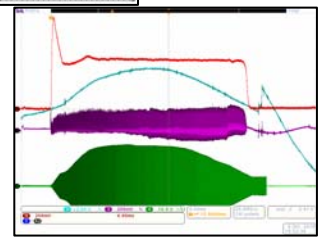
d: *q*=1, *A*=2, *q*/*A*=1/2

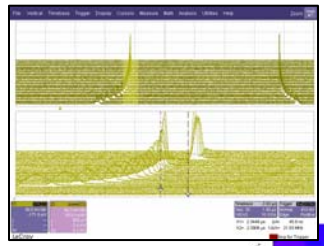


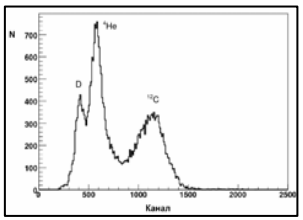
C: *q*=6, *A*=12, *q*/*A*=1/2

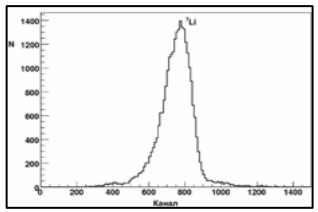
	Deuterons $^{2}H^{1+}$	Carbon $^{12}C^{6+}$
U1.5	16.7–448.6 MeV/u March 30, 2008	16.7–455.4 MeV/u December 08, 2010
U70	23.6 GeV/u April 27, 2010	34.1 GeV/u April 24, 2011
		SE @ 455 MeV/u April 24, 2011
		24.1 GeV/u in BTL#22 & FODS April 27, 2012

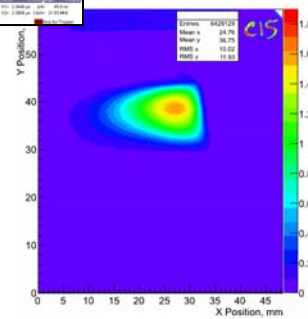












Conclusion

Accelerator Complex *U*70 of IHEP-Protvino:

- comprises 4 machines (*URAL*30, *I*100, *U*1.5, and *U*70 itself),
- readily ensures running the fixed-target physics program,
- is subject to ongoing upgrade program,
- has noticeably improved quality of proton beam,
- is on a way towards routine acceleration of light-ions to 24-34 GeV per nucleon for high-energy nuclear physics
- now has slow extraction of 455 MeV per nucleon of $^{12}C^{6+}$ beam
- *U*1.5 and *U*70 now belong to PS and (L)IS categories