



National Research Center "Kurchatov Institute"
INSTITUTE FOR HIGH ENERGY PHYSICS (IHEP)
Protvino, Moscow Region, 142281, Russia

Accelerator Complex U70 of IHEP: Status and Upgrades (report TUX02)

Sergey Ivanov
on behalf of the U70 staff

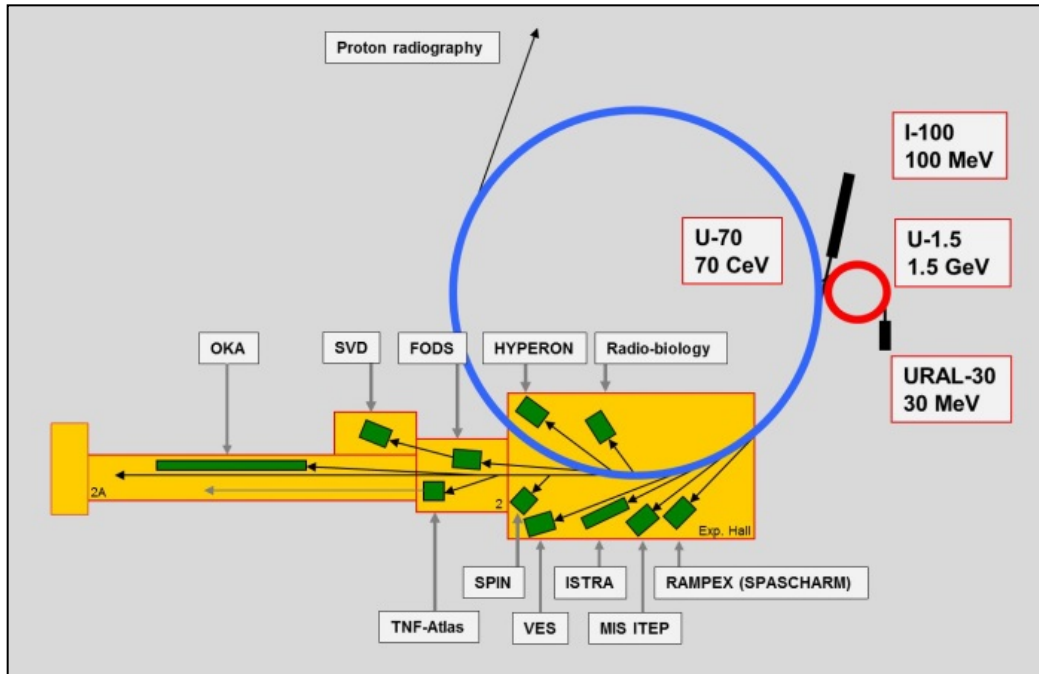
XXIV Russian Particle Accelerator Conference
RuPAC-2014
October 6-10, 2014, Obninsk, Kaluga Region, Russia



- Generalities
- Routine operation
- Machine development, run by run (5)
- Conclusion

Emphasis on a progress since RuPAC-2012

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

Light-ion:

- high energy 24.1-34.1 GeV/u
- intermediate energy 453-456 MeV/u



November 15, 1963-2013

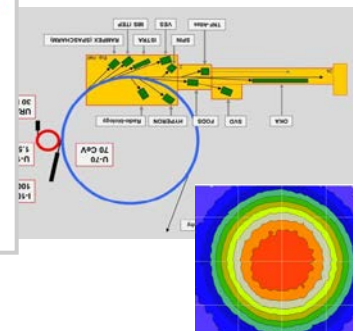
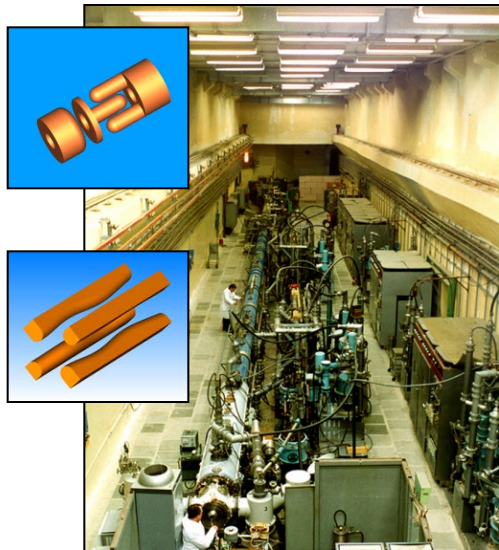
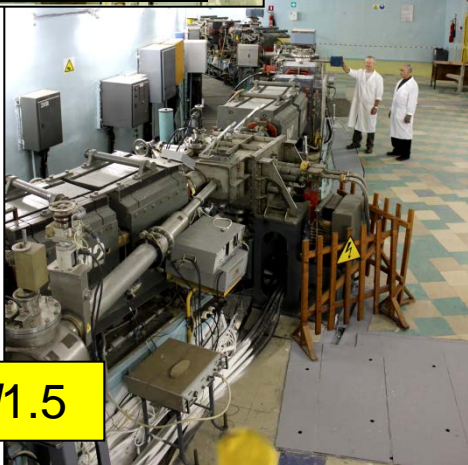


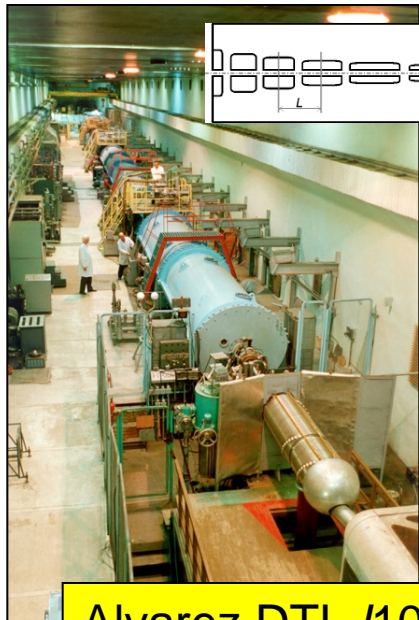
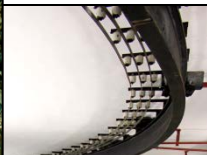
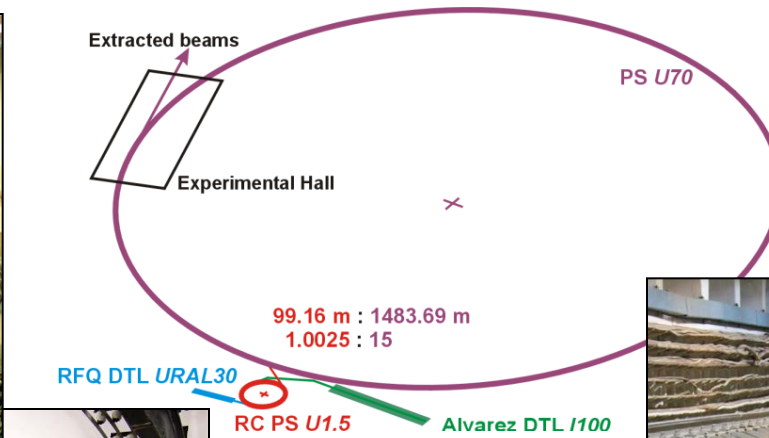
Photo album of machines



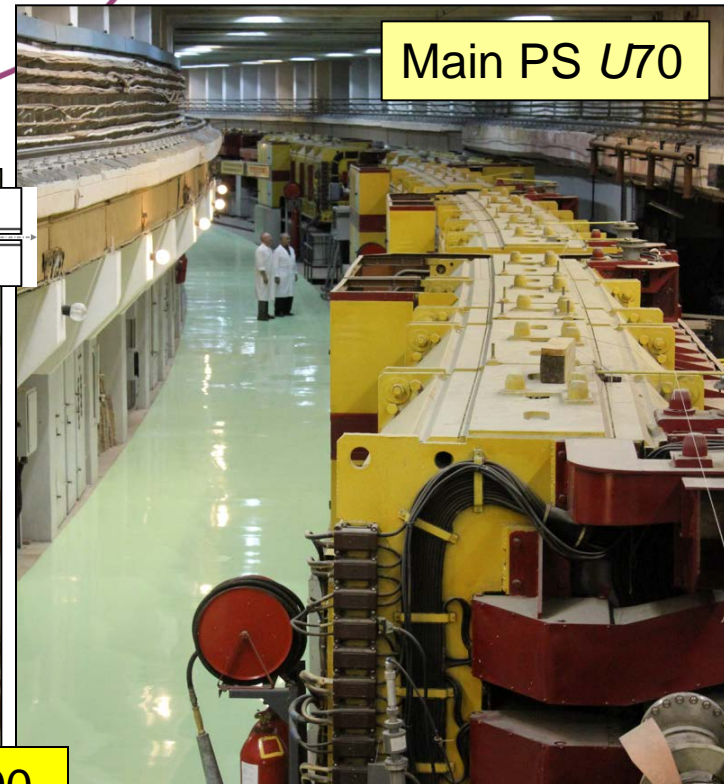
RFQ DTL URAL30



RC PS U1.5

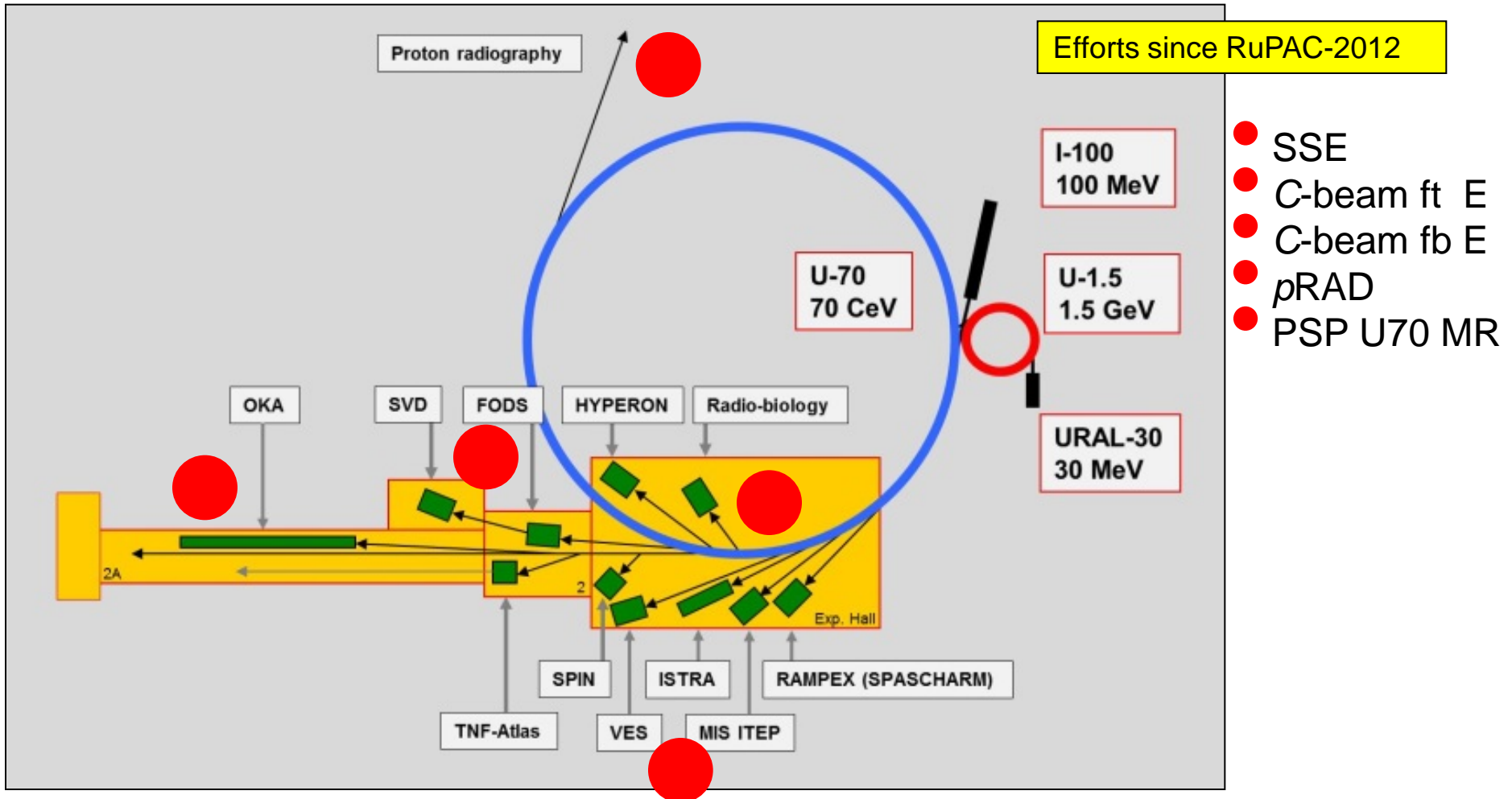


Alvarez DTL I100



Main PS U70

Points of Attraction



Light ion program

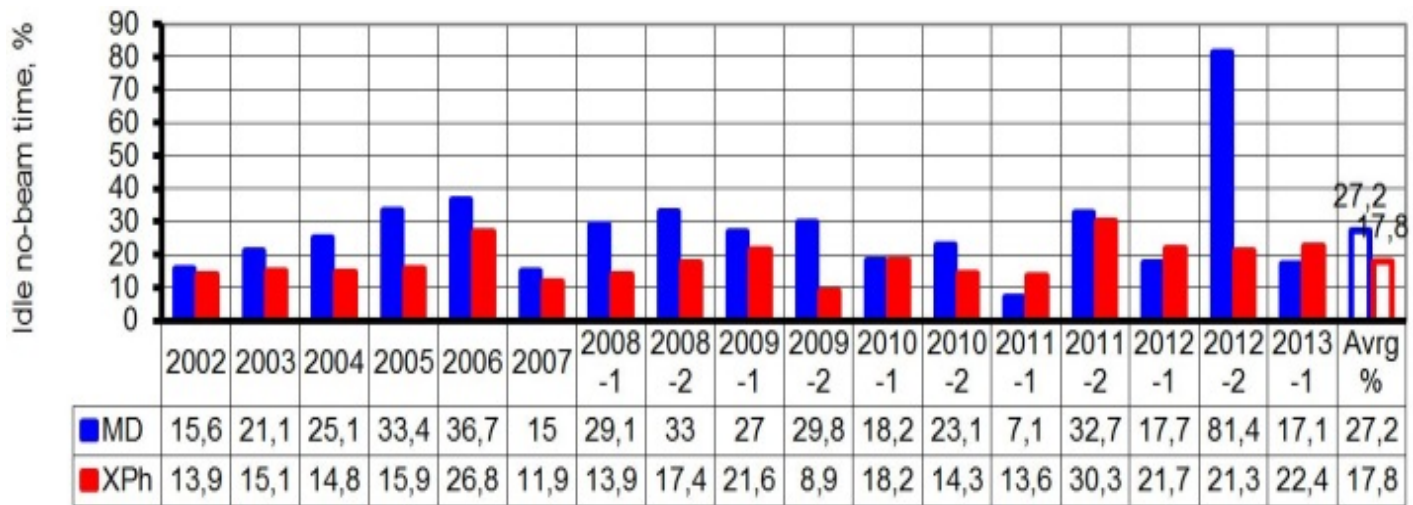
	Deuterons $^2\text{H}^{1+}$	Carbon $^{12}\text{C}^{6+}$
U1.5	16.7–448.6 MeV/u March 30, 2008	16.7–455.4 MeV/u December 08, 2010
U70	23.6 GeV/u April 27, 2010	34.1 GeV/u April 24, 2011
		SE @ 455 MeV/u April 24, 2011
		24.1 GeV/u in BTL#22 & FODS (300 GeV full) April 27, 2012
		Validation tests of top-energy extractions with ion beam April 24, 2013

Statistics

2 runs (7/24) per year:

- short (XPh 10 days ca) 2 MD(p) + ions
- long (XPh 30 days ca) 3 MD(p) + ions

Avrg %
27,2
17,8

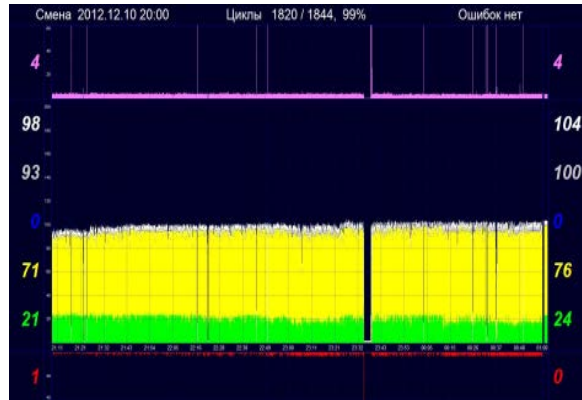
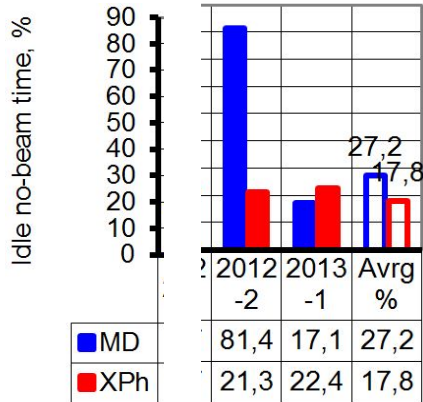


Beam availability for physics = 82.2%

2013 -2	2014 -1	2014 -2
n/a	n/a	n/a

5 runs since RuPAC-2012

Run 2012-2, protons

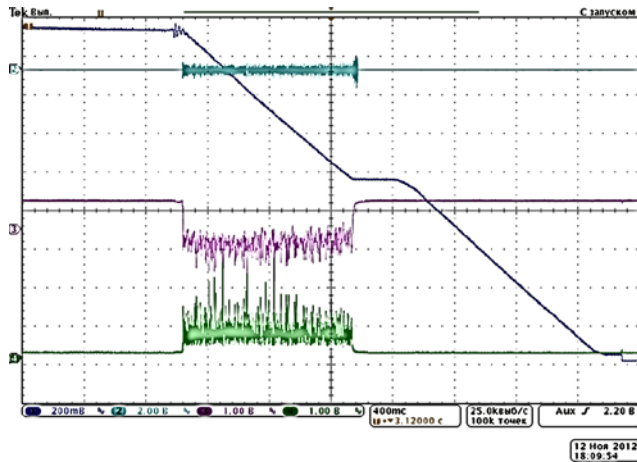


4% loss

$1.05 \cdot 10^{13}$ ppp

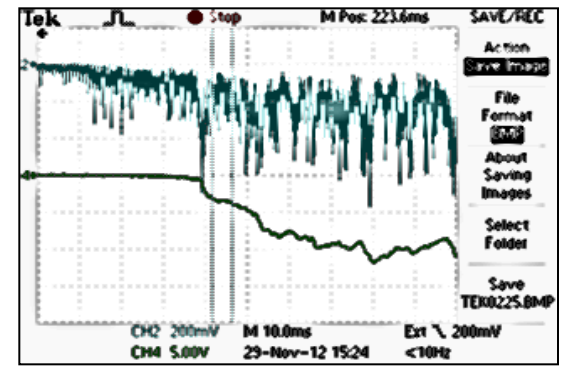
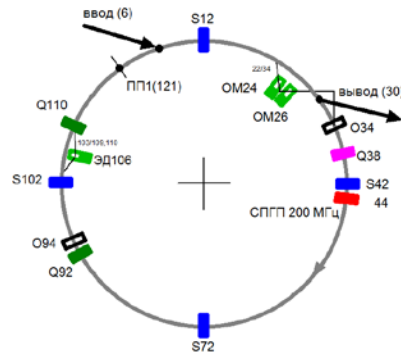
$7-7.6 \cdot 10^{12}$ ppp via SEE

← 3 hr, or 1000 cycles →



1.26 s spill

An issue left with the SSE:
a low in-out = 85-87% (90% occasionally)
+ a trend to decrease at higher N

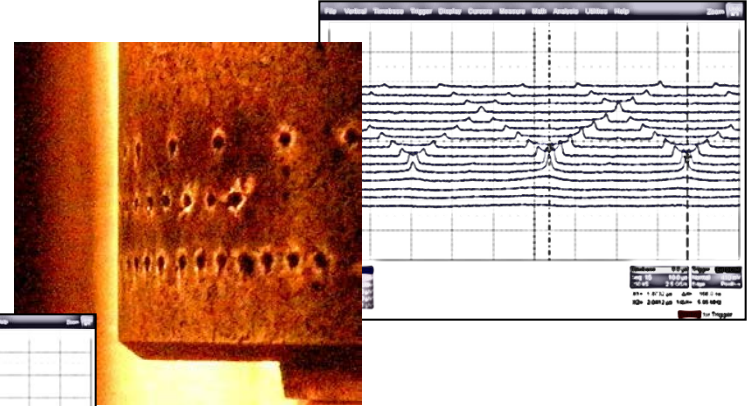


Run 2012-2, carbon ions

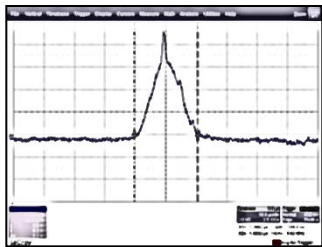
Test p beam, RF gymnastics

I100 12-14 mA pulsed 4300 shots per spot (9.5 hr survival)

C to $5 \cdot 10^9$ ipp (in 8.3 s) 24.1 GeV/u (300 GeV full)
BTL#22 (190 m) to FODS

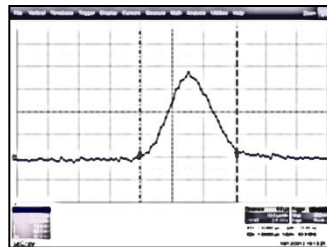


Flat bottom



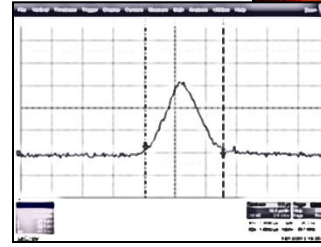
100-120 ns

Transition crossing



10-16 ns

Flattop

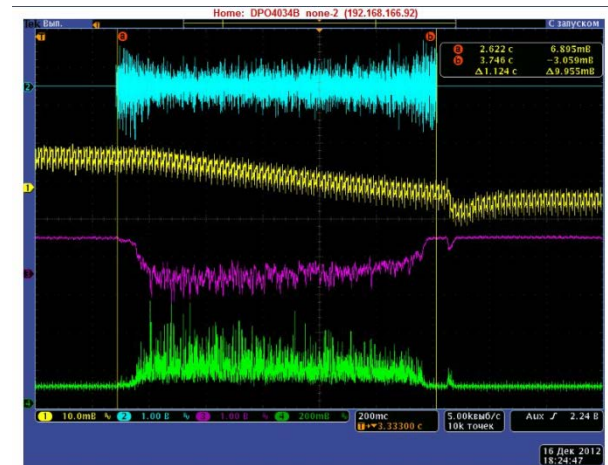
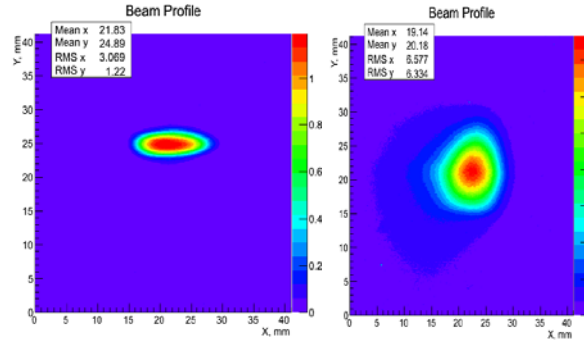
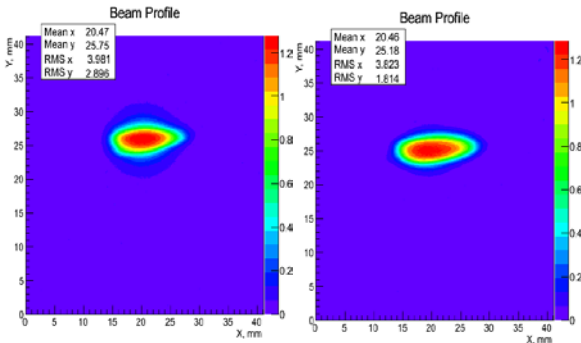


20-25 ns

SSE, C, 24.1 GeV/u, $1.7 \cdot 10^9$ ipp 1 s spill

p 0.82 in-out

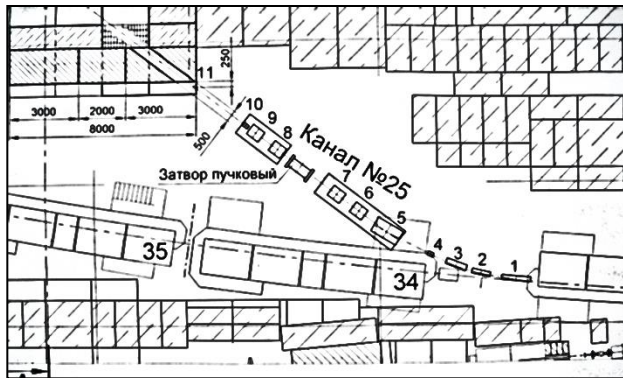
C 0.77 in-out



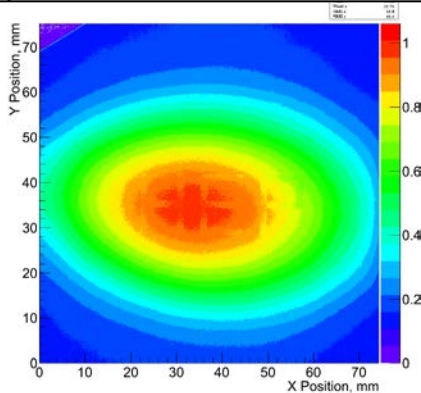
Run 2013-1, ions

Start with a stand-alone DC PSU (130 A) of U70 MR 1.32 GeV (p):

- Hot run-through of the URAL30 linac
- Beam commissioning of the new BTL#25 (upstream part) with a p -beam C- beam 24.1 GeV/u (300 GeV full) BTL#22 (190 m) to FODS & SVD



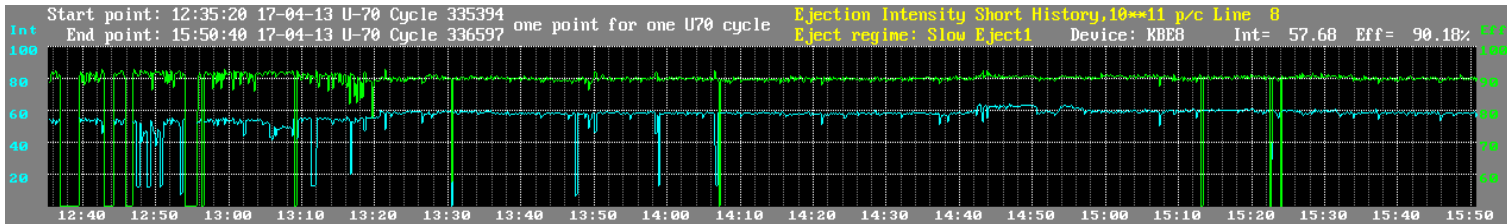
BTL#25: 6.9 T·m, 18 m, 3 dipoles, 4 quads and 2 vertical correctors



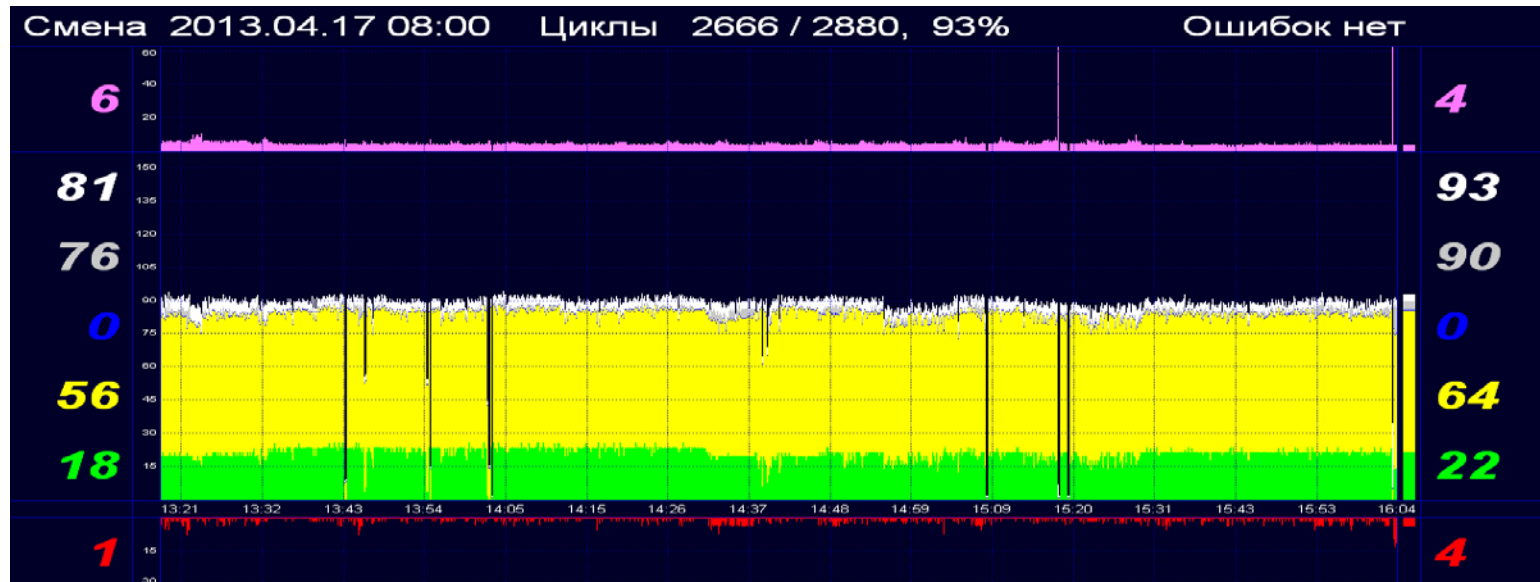
C beam footprint @ exit BTL#25, 7 x 5 cm² ca

Run 2013-1, protons

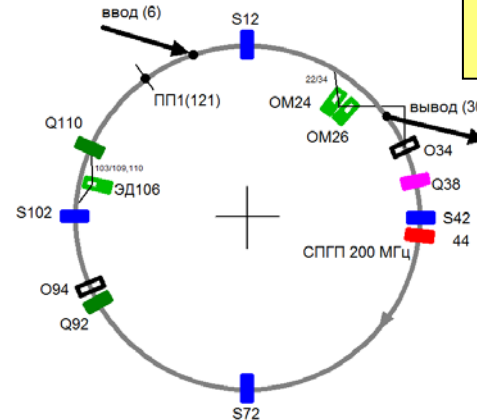
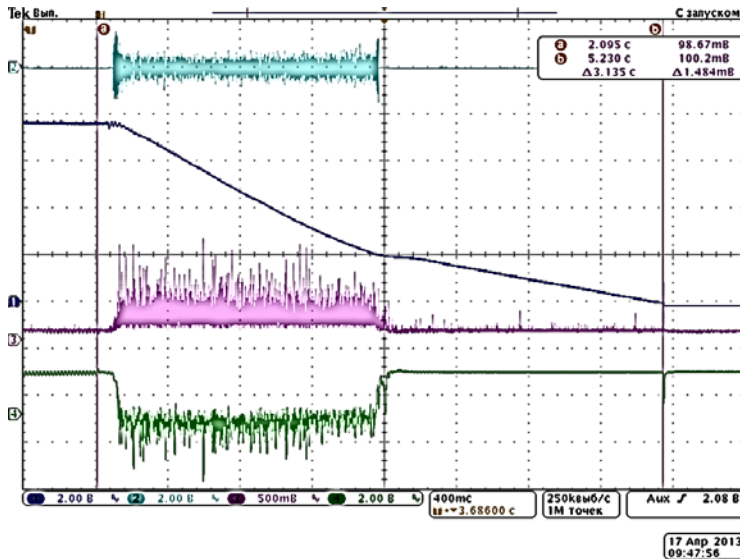
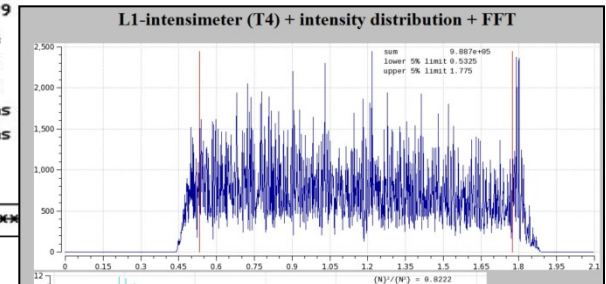
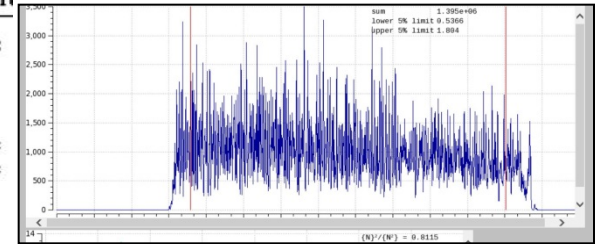
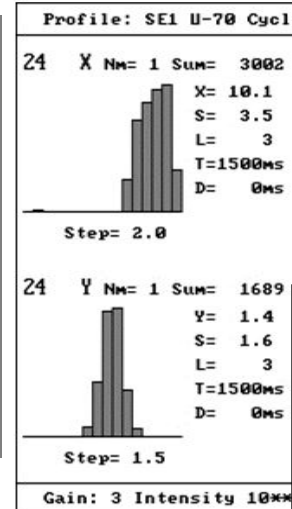
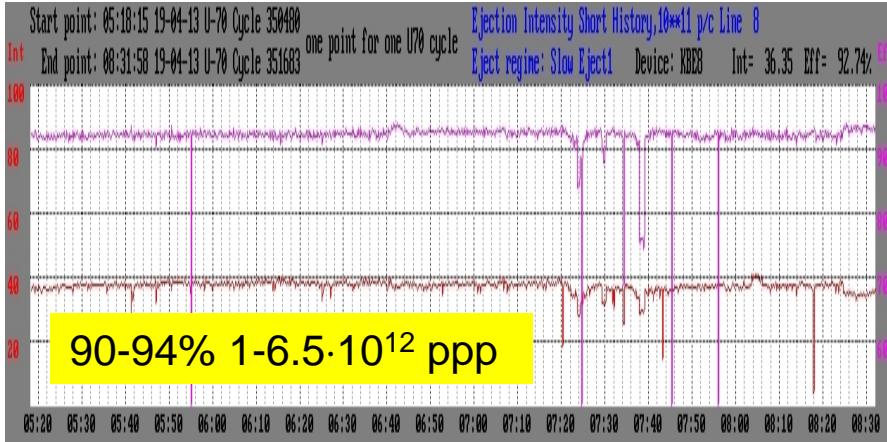
- Repair of correction $B \propto x^2$
- Eliminate malfunctioning of correction $B \propto x^3$



90-94%
 1-6.5·10¹² ppp



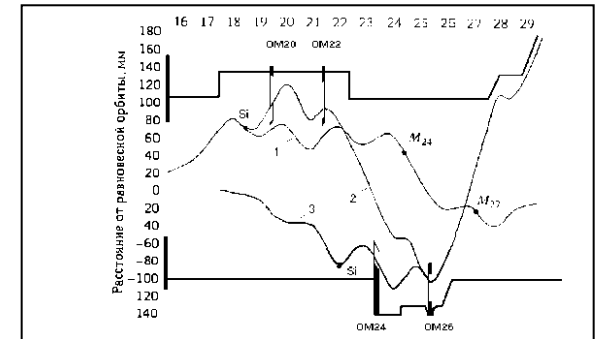
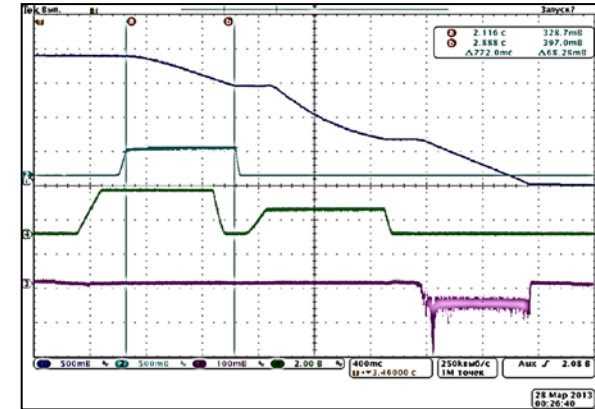
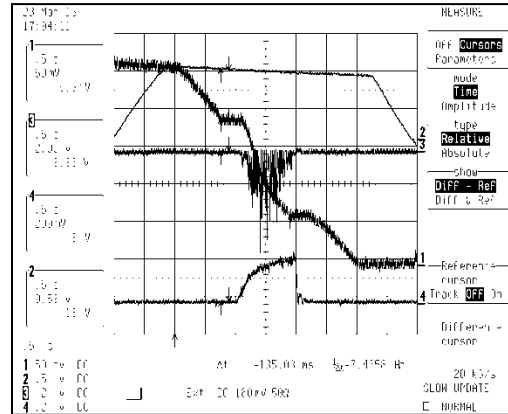
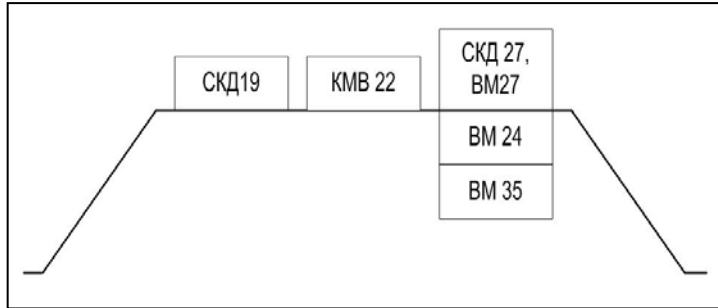
Run 2013-1, protons



duty factor $\langle \Phi \rangle^2 / \langle \Phi^2 \rangle$ to 0.82.
 No lines of mains harmonics

The best ever record
 of the top-energy
 SSE operation

Run 2013-1, protons



- Triple flattop sharing
- TNF-Atlas, CD-SE, from $1 \cdot 10^6$ to $4 \cdot 10^{11}$ ppp (>5 orders of magnitude!)
- CD-SE with CD#22 carbon 24 GeV/u 0.7 s min $N = 1.5 \cdot 10^7$ ipp. Still, lower values are in a demand
- Prospects of CD-SE of C-beam tbc (fragmentation)

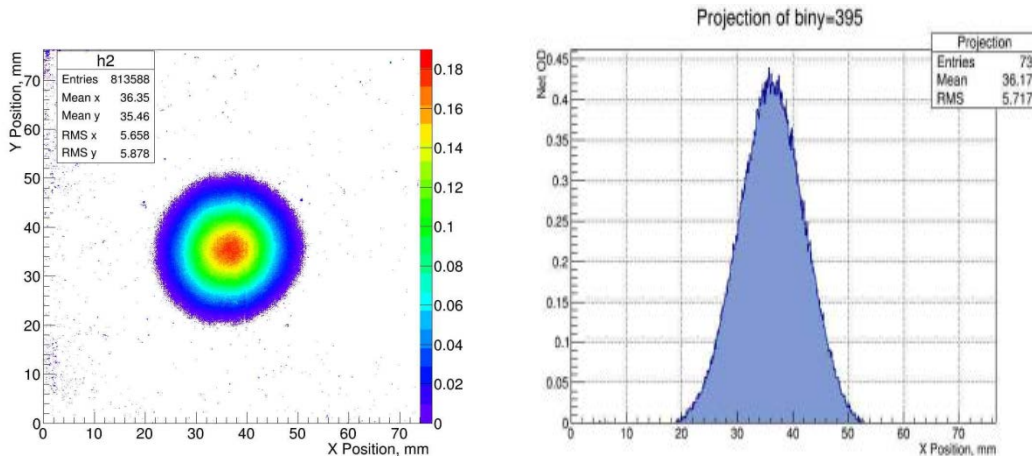
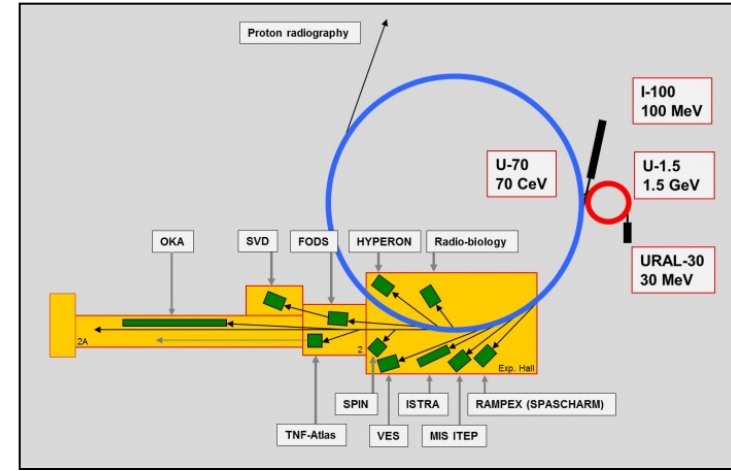
Two flat-bottom runs, 2013-2, 2014-1

U70 MR fed by a stand-alone DC PSU yielding 130 A (field 353.7 Gs)

U70 as a beam storage and stretcher ring for:

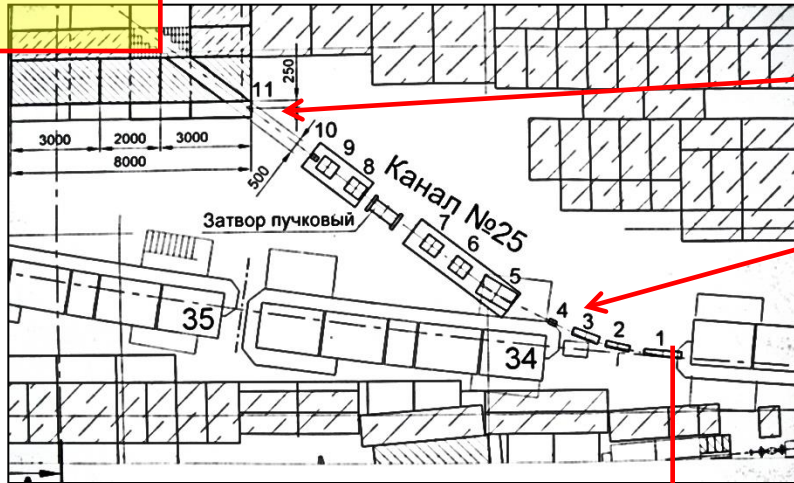
- 1.32 GeV (protons) or
- 455.7 MeV/u (carbon nuclei)

U1.5 booster = the full-energy injector



@ exit BTL#25, diameter = 3 cm @90% population

IRBWb



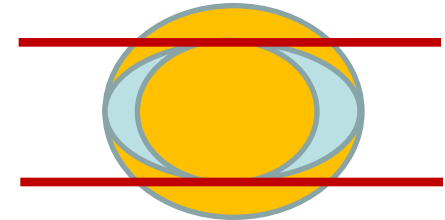
Wobbler

Alignment

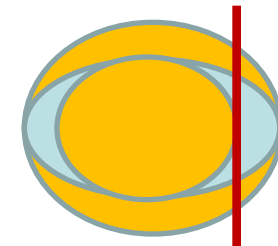
Stray field, $\lambda/2$ bump @ M#39-40

- Localized to 6 blocks
- Noise and diffusion

Vertical



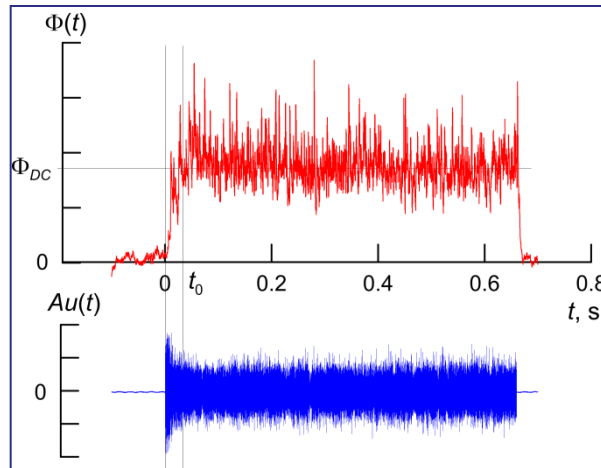
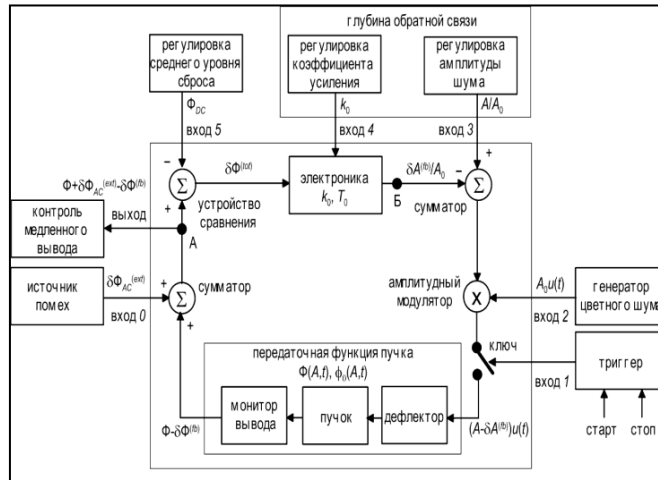
Horizontal



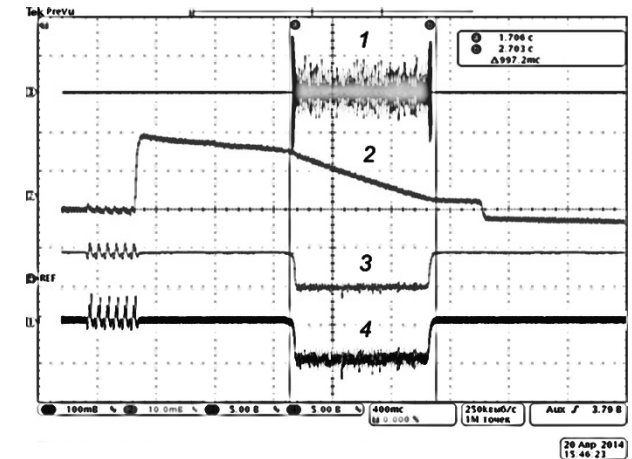
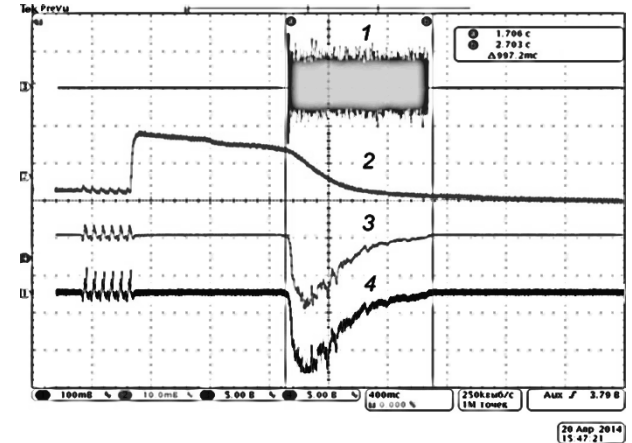
SE in-out efficiency:

- 8–10% for test protons, top expected 30% ca
- 45–50% (occasionally, to 57%) for carbon nuclei, top expected 80% ca

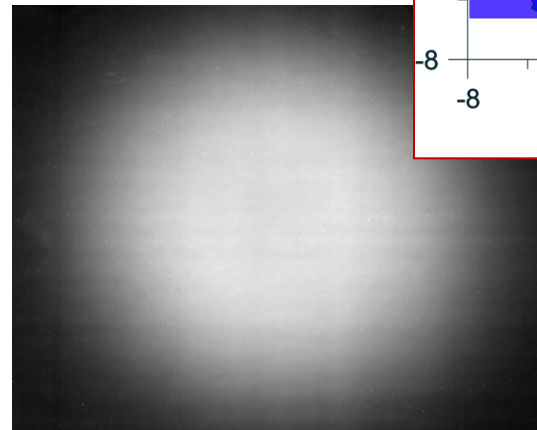
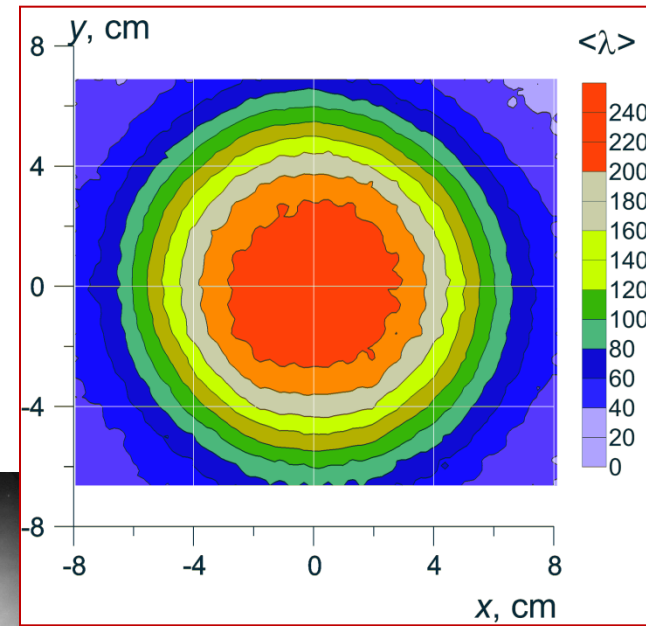
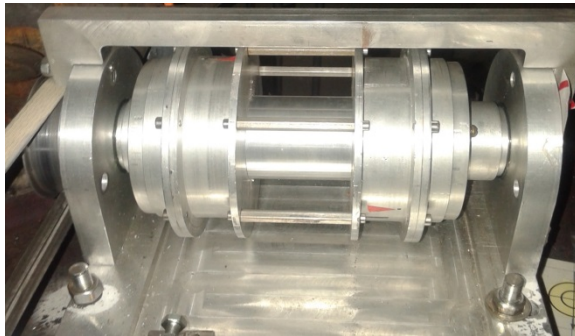
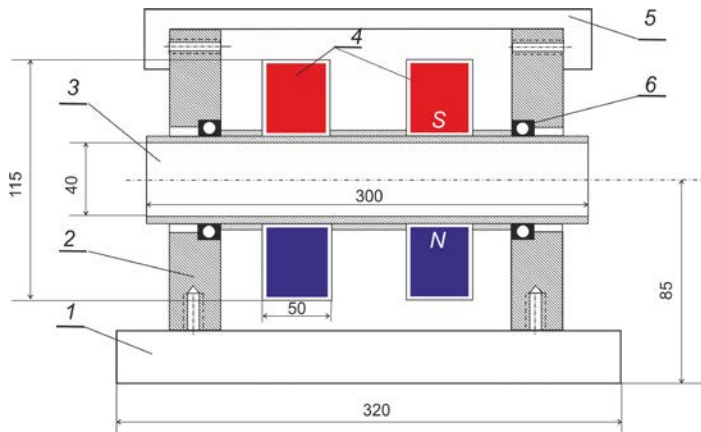
Beam temporal structure



Transverse noise diffusion
 Beam feedback
 Square-wave pulses
 Spills 0.6-1 s long

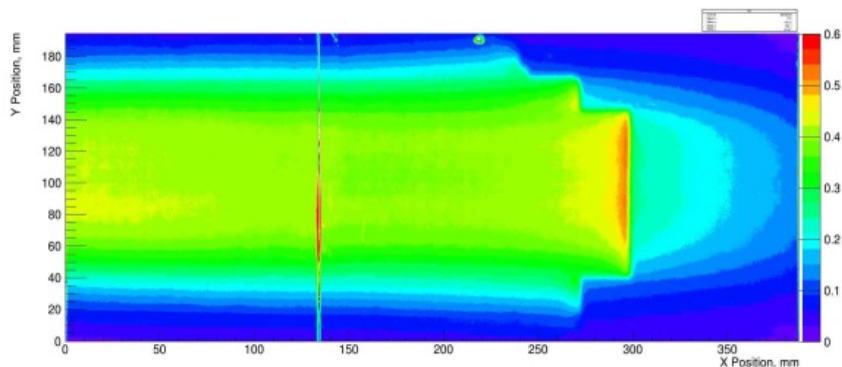


Beam transverse spatial structure

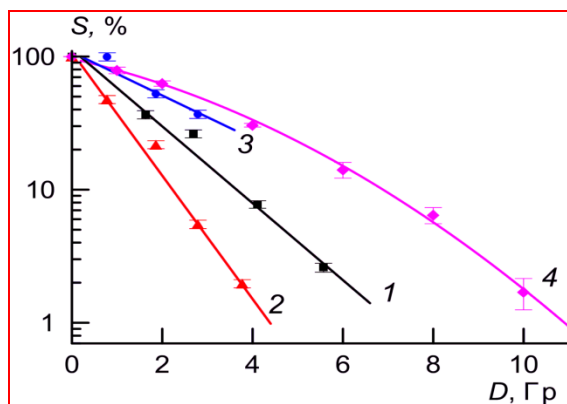


>95% flatness at $R = 3$ cm

Beam longitudinal transverse structure



Natural Bragg's law
30 cm stopping range in a water phantom



Experimental Dose-Effect curve
1st radiobiological experiment with Carbon beam from the U70

by Medical Radiological Research Center
of the Russian Ministry of Health (Obninsk, Kaluga Region)

Details in the poster WEBSB19 by V. Pikalov et al, tomorrow

New PS plant of the U70 1.5 km ring magnet



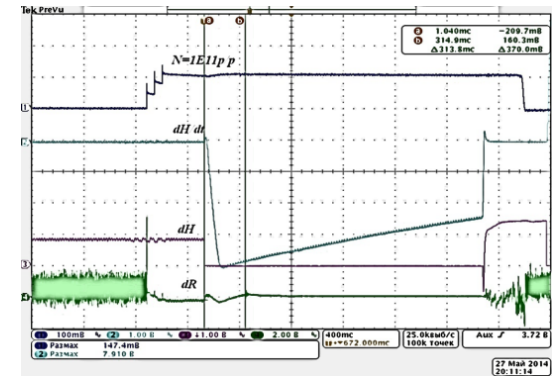
108 t, 220:10 kV



LLC "NIEFA-Energo" (St.-Petersburg)



1st proof-of-workability ramping to 50GeV (p) with the new PSP



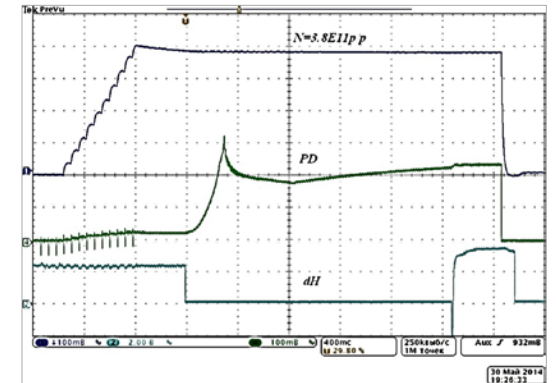
Beam commissioning of Proton-Radiographic Facility

with RFNC-VNIIEF (Sarov, N. Novgorod Region)



Ø200 mm field-of-view and a sub-mm resolution for a > 450 g/cm² optical density object

180°FODOFODO quadruplets of 24 paired side-by-side wide-aperture (hole Ø300 mm) quadrupole lenses with the top field gradient 6.7 T/m



Conclusion

Accelerator Complex U70 of IHEP-Protvino is a subject to an ongoing upgrade program aimed at extending the machine functionality for fixed-target research,

- both fundamental and applied,
- with protons and carbon nuclei
- of high and intermediate energies,
- slowly or fast extracted.

Run 2014-3 starts just now, October 6, 2014