NATIONAL RESEARCH CENTRE
«KURCHATOV INSTITUTE»

INSTITUTE for HIGH ENERGY PHYSICS
Protvino, Moscow Region, 142281, Russia

Status of U70

(report TUZMH01)

Sergey Ivanov

on behalf of the U70 staff

XXV Russian Particle Accelerator Conference

RuPAC-2016

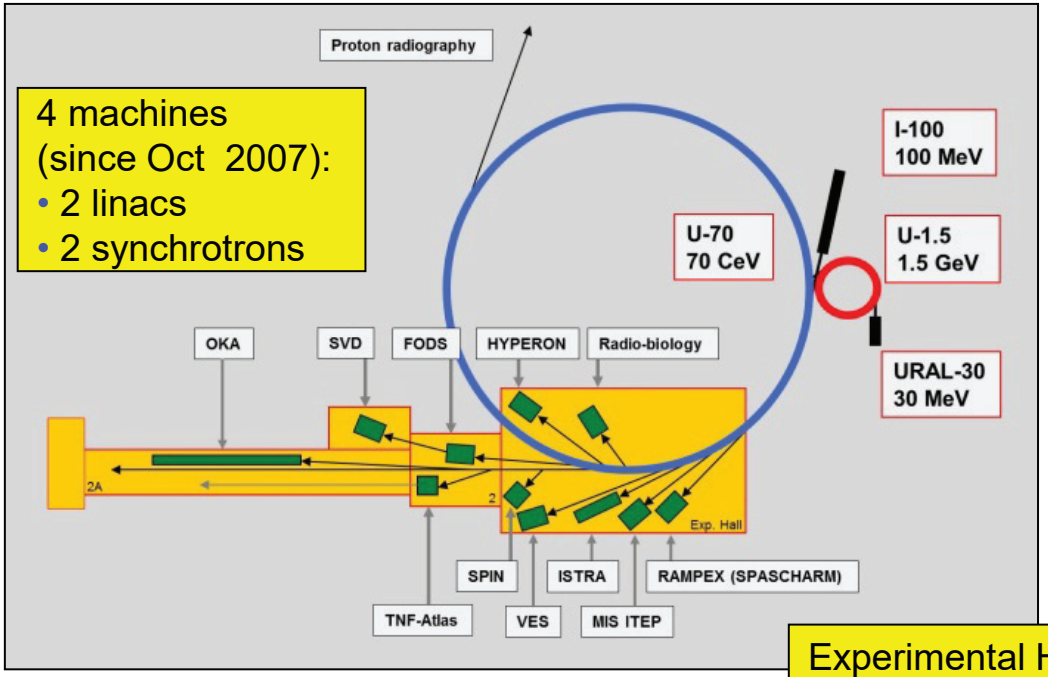
November 21-25, 2016, St. Petersburg / Petergof, Russia

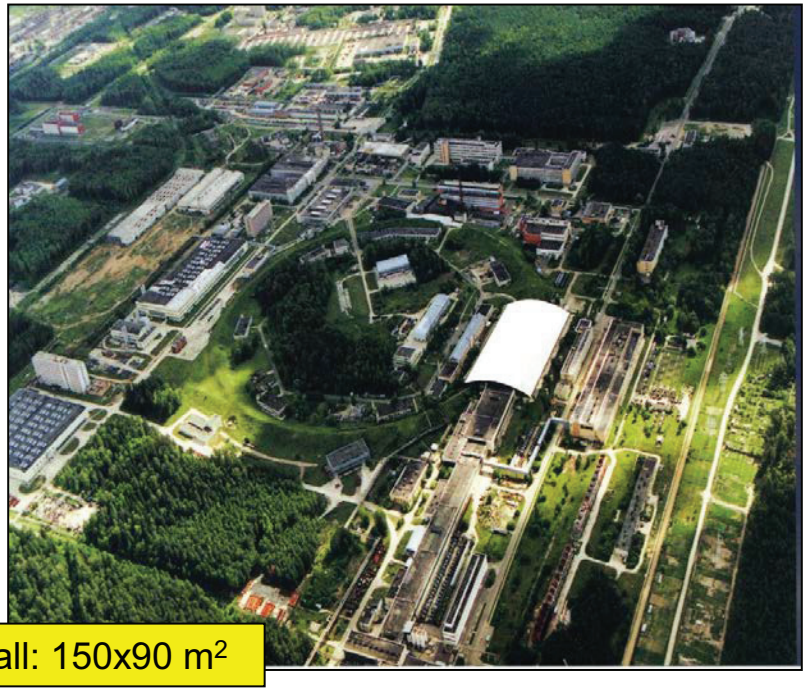
Outlook

- Generalities
- Routine operation
- Machine development, run by run (4)
- Conclusion

Emphasis on activity since RuPAC-2012

Layout





Experimental Hall: 150x90 m^2

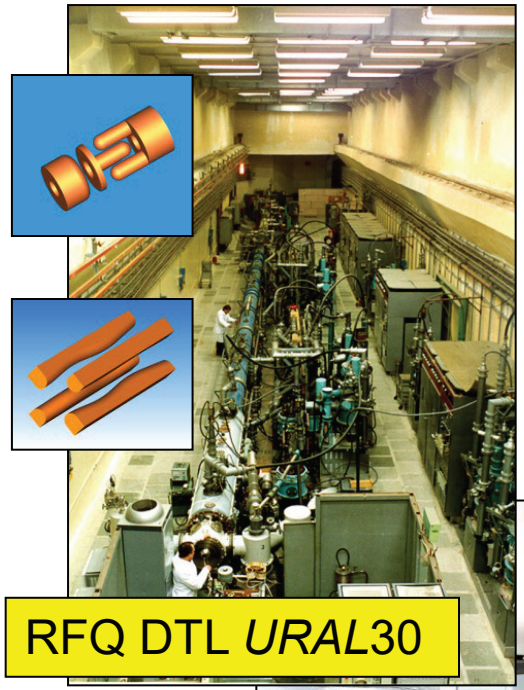
Моды:

• proton (default, [20, 25], 50-70 GeV)	URAL30-U1.5-U70
• light-ion (C, complementary)	I100(2 of 3)-U1.5-U70

Carbon nuclei:

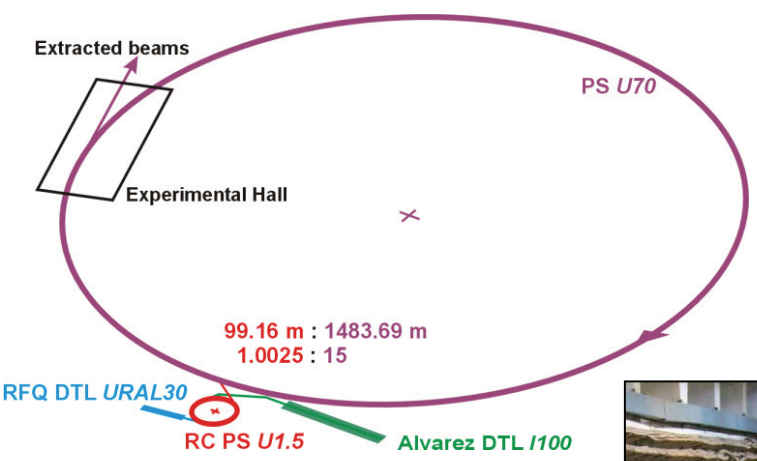
• (*of very*) high energy	[20] 24.1-34.1 GeV/u
• intermediate (*still high*) energy	455-6 MeV/u

Photo album of machines

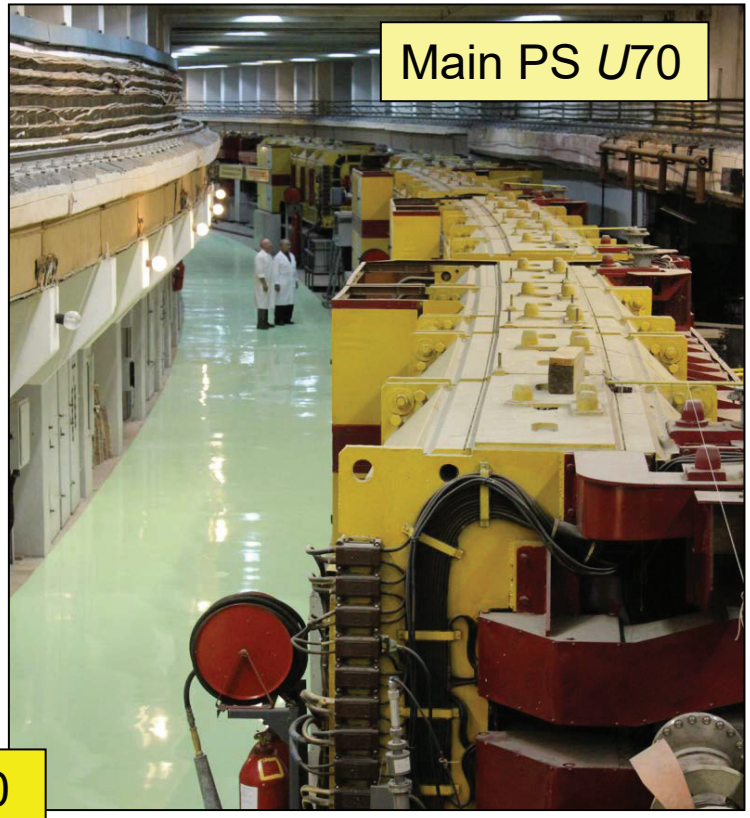


RFQ DTL *URAL*30

RC PS *U*1.5



Alvarez DTL *I*100



Main PS *U*70

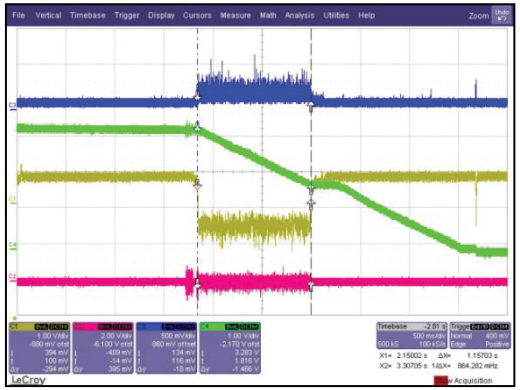
Extractions from U70

Inventory to service fixed-target research:

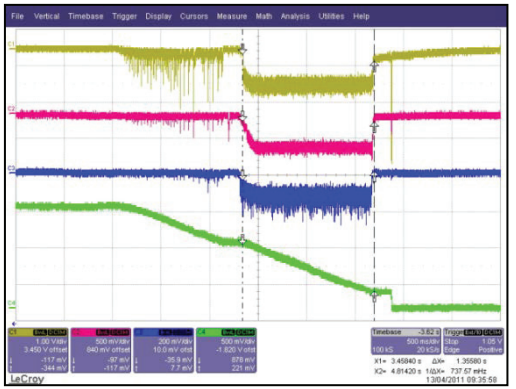
- IT, secondary particles
- 1-turn/to 1-buch FE
- RSE (Q38 & SSE (new))
- CD (new)
- SSE*t* @ flat-bottom (new)
- Mutlti-turn (4-10) FE (new)

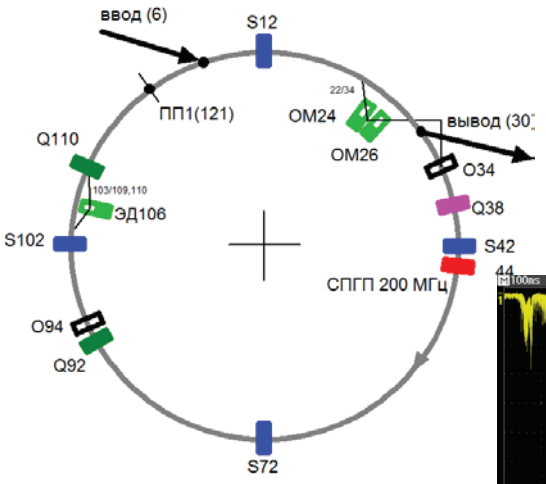
Sequential and parallel beam sharing at flattop

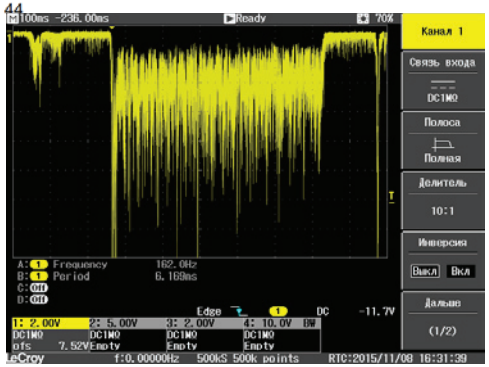
1st t ½ flattop, SSE



2nd ½ flattop, IT and CD

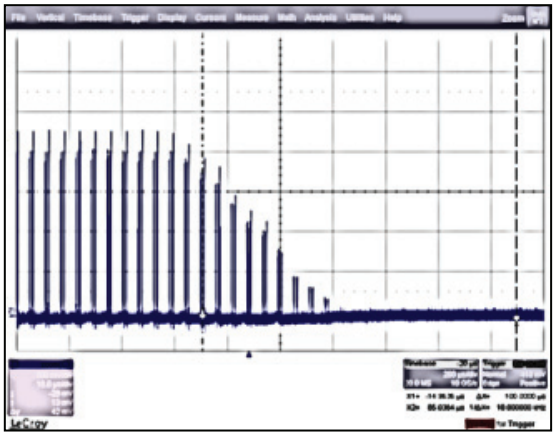


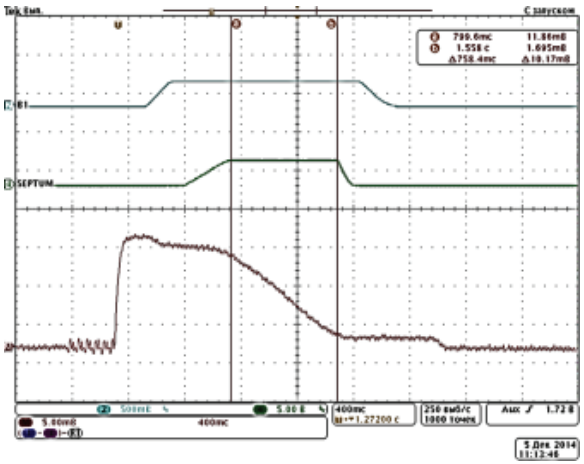


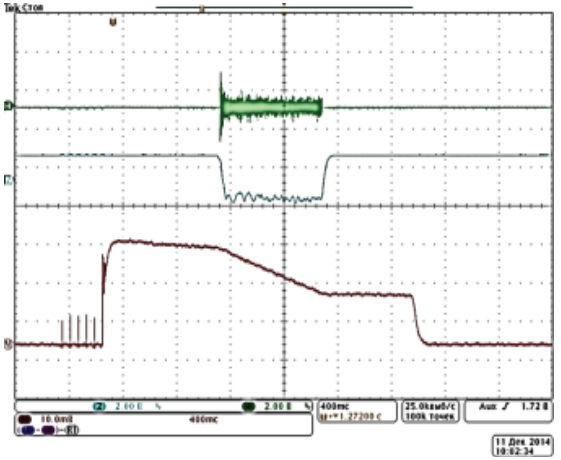


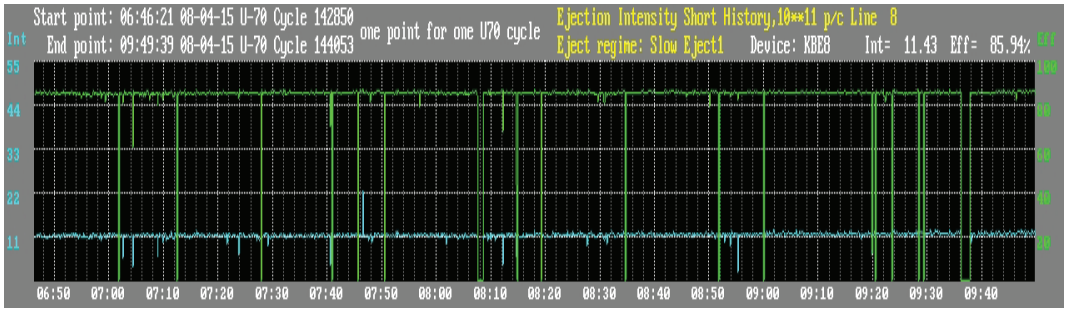
Duty factor $\langle\Phi\rangle^2/\langle\Phi^2\rangle$ to 0.8-0.9.
No lines at multiples of 50 Hz
In-out transfer to 93%

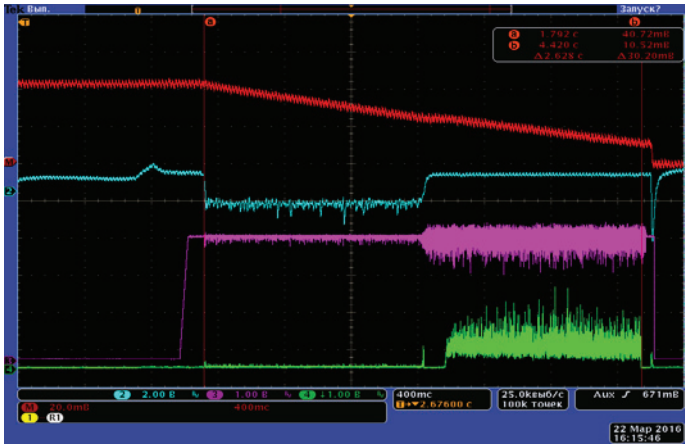
Oscillograms of extractions

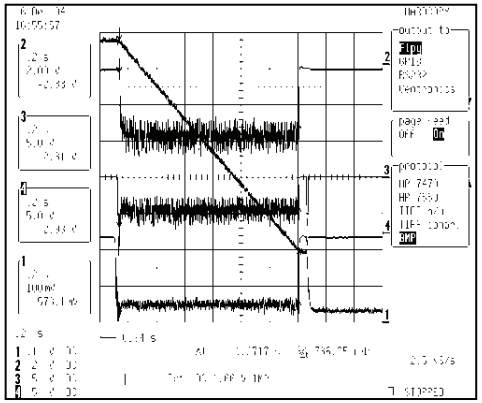








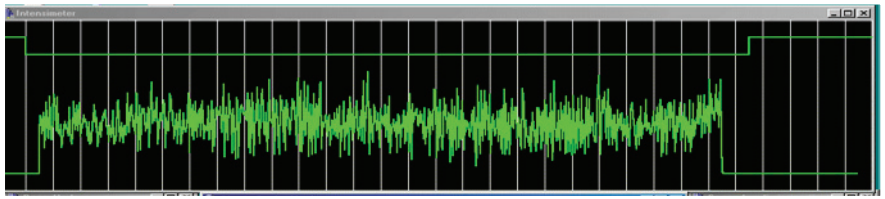




CD19

IT24

IT27

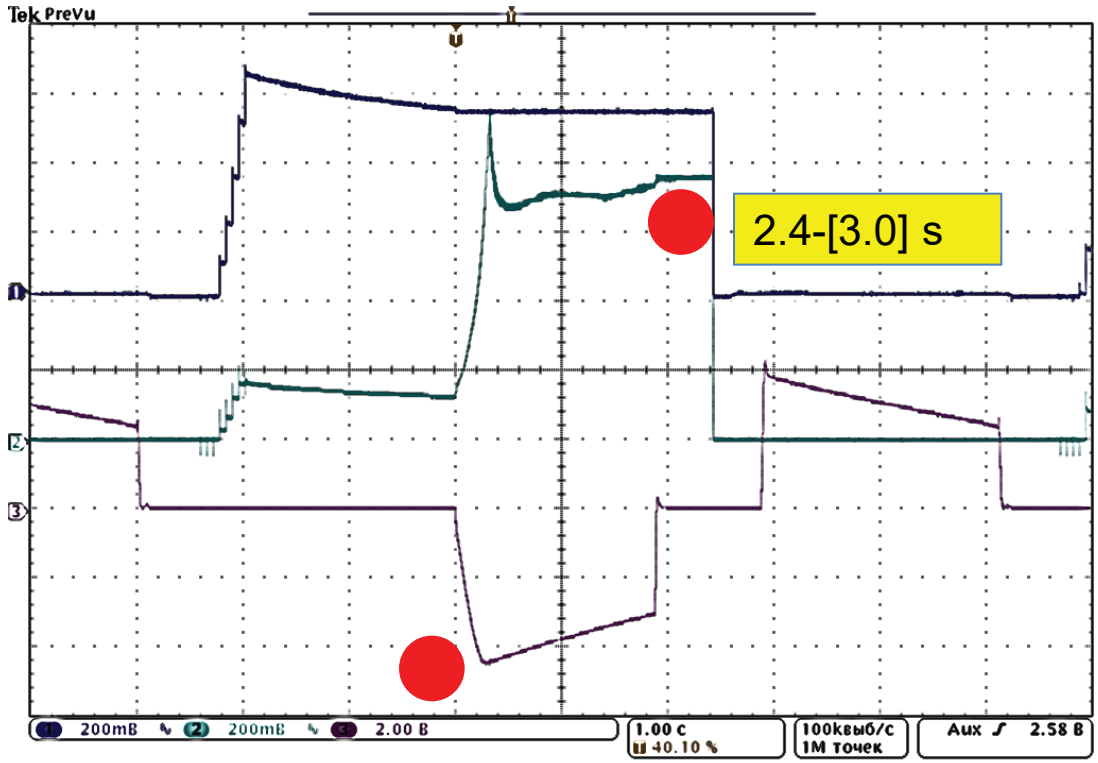


Overview of recent runs

Run	Specifics
2014_1	DC PSU: 1.3 GeV (*p*), 455 MeV/u (*C*); SSEt, out/in, *R*=3 cm (95%), 1st radiobiology, "hot" conditioning of U70 subsystems
2014_2	50 GeV (p); 1st test of new PSP for U70 ring magnet; commissioning of large-scale pRAD facility
2014_**3**	50 GeV (p) and 1st XPh run with the new PSP for U70; high priority for pRAD facility with 1-turn FE and multi-turn FE(3-10); 455 MeV/u (*C*) for radiobiology (as the major user)
2015_1	5 regimes: (1) nonstandard **25 GeV** *p* XPh; (2) 50 GeV *p* XPh without pRAD; (3) 50 GeV *p* pRAD + XPh; (4) 25 GeV/u *C* XPh; (5) 456 MeV/u (*C*) for radiobiology
2015_2	User program partition: | XPh-1 | **pRAD** +XPh-2 | XPh-3 |; 455 MeV/u (*C*) for radiobiology
2016_1	**40 GeV** (*p*) pilot beam; 20 GeV/u (*C*) XPh (3 facilities via SSE and CD); 50 GeV (*p*) pRAD + XPh; 455 MeV/u (C) for radiobiology
2016_2	In progress

Run 2014-3. New U70 RM PSP

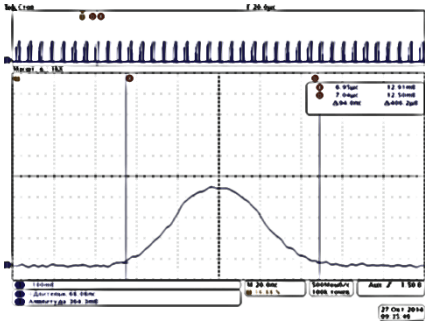
Adequate “single-particle” acceleration



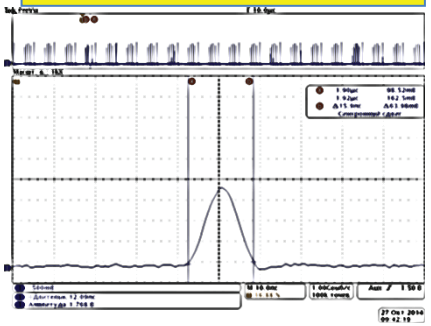
29 Oct 2014

Double-section filter
Ttr – KC! = 350 ms
Single-section filter
Ttr – KC1 = 286 ms
dB/dt = 0.82 T/s

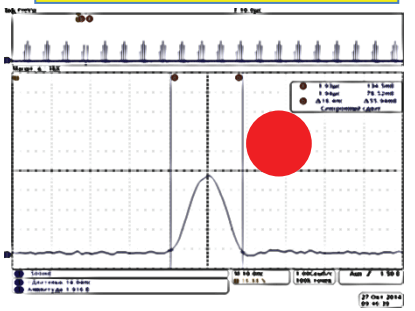
Flat bottom 94.0 ns



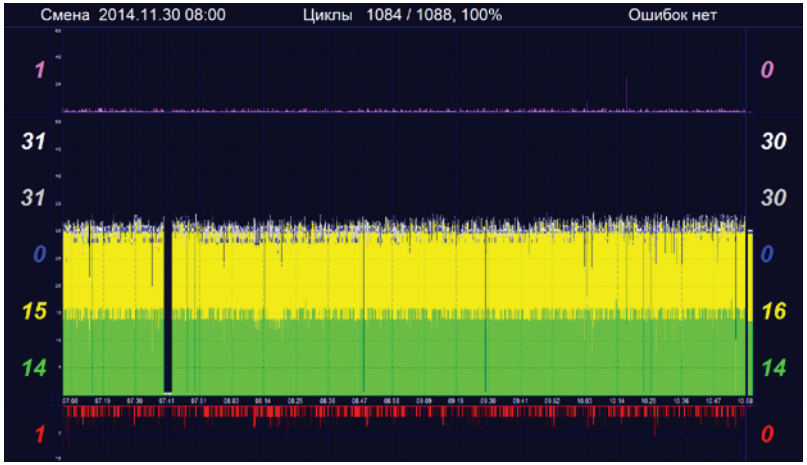
Transition 15.9 ns

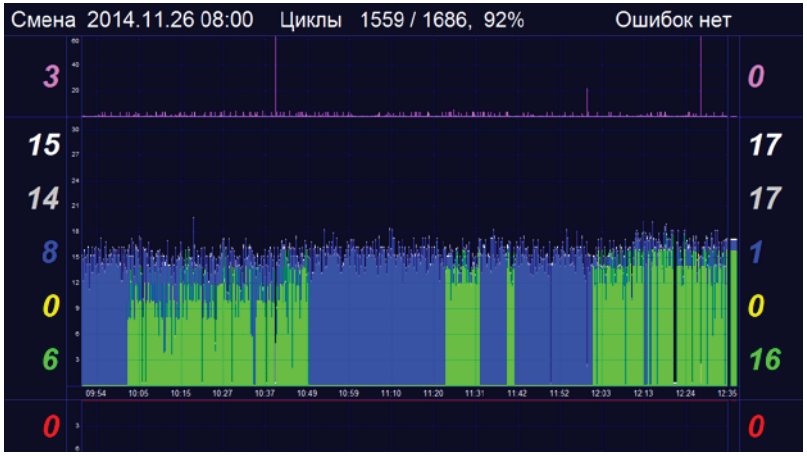


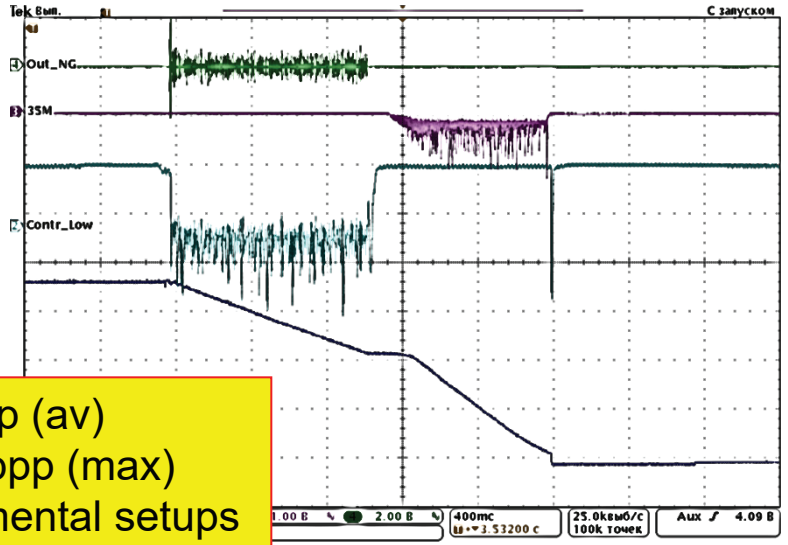
Flattop 18.4 ns



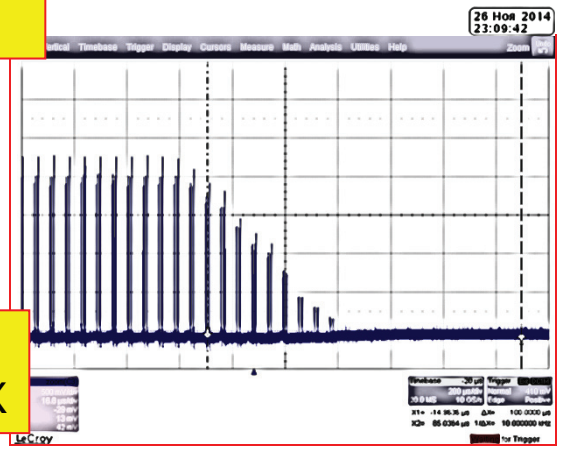
Run 2014-3. Experimental program







$3 \cdot 10^{12}$ ppp (av)
$3.8 \cdot 10^{12}$ ppp (max)
7 experimental setups
80-85% in-out SSE



bump 20-26,
off BTL#24, RAMPEX

Run 2014-3. Carbon 455 MeV/u

Upstream of beam

U70:

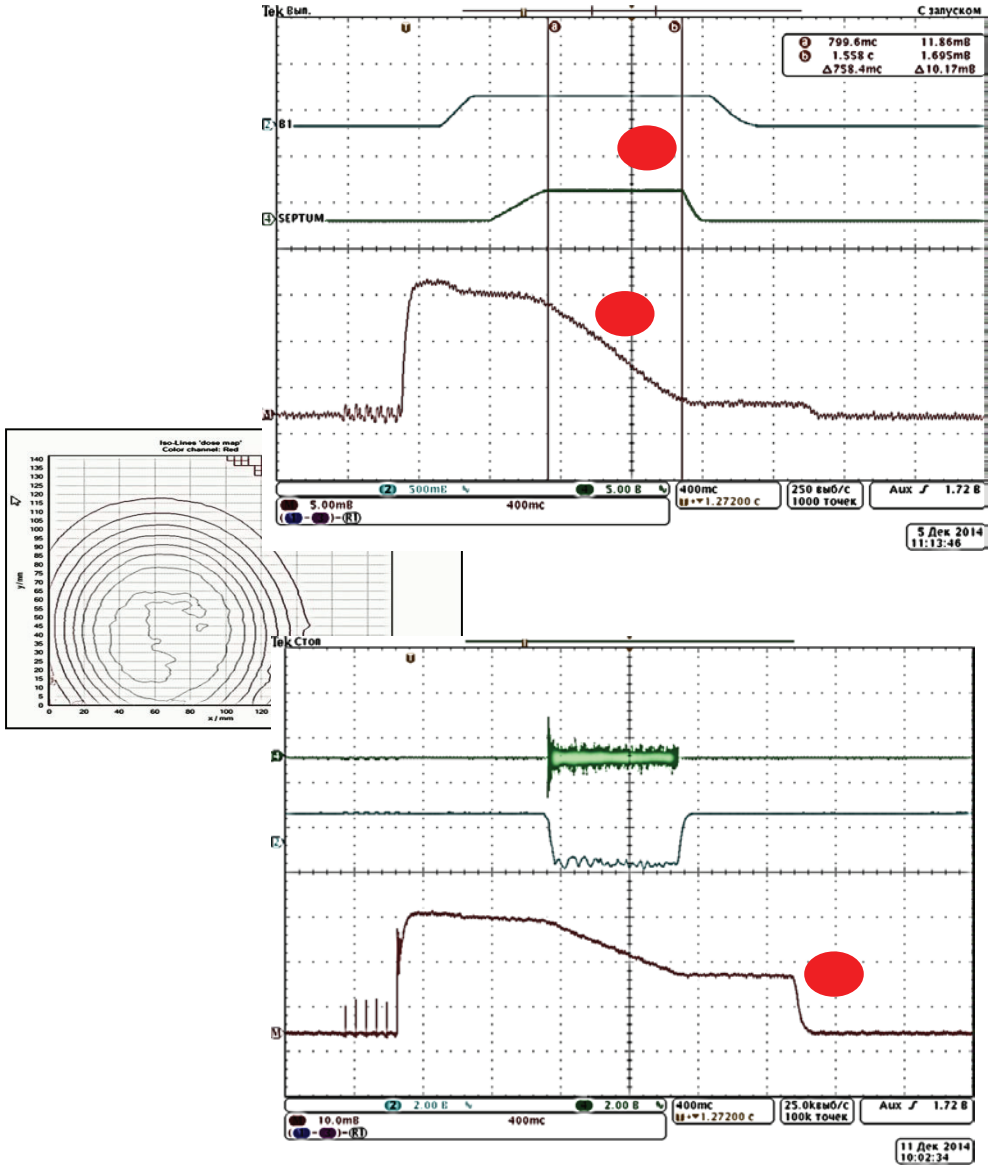
- 2.1-2.8·10^9 ipp in U70
- 1.2-1.9·10^9 ipp in BTL#25
- П-spill 0.6 s every 8.2 s
- SSE in-out 55-57% [68%]

U1.5:

- accelerates….

I100:

- 1 week stand-alone, 2 weeks in cascade
- 17-18 mA (22 mA max)
- 90-92% over BTL I100-U1.5
- RF 4 s 7/24
- Laser ion source 8 s 7/12



Run 2015-1. Specifics

1	25 GeV *p* XPh	new PSP RM U70 non-standard energy	169 hr	$2 \cdot 10^{12}$ ppp 10-12 bunches
2	50 GeV *p* XPh without pRAD		294 hr	$6 \cdot 10^{12}$ ppp -20 bunches
3	50 GeV *p* pRAD + XPh		318 hr	$3 \cdot 10^{12}$ ppp @ ФП 6-8 users.
4	25 GeV/u *C* XPh	new PSP RM U70 purity of C beam no fragmentation due to CD	50 hr	$4 \cdot 10^{10}$ qpp
5	456 MeV/u *C* RB	without test *p* beam	52 hr	$2\text{-}4 \cdot 10^{10}$ qpp

Run 2015-1. Extractions

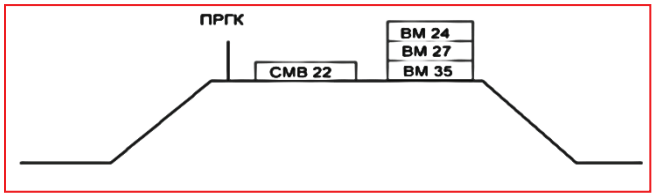
Extraction 25 GeV *p*

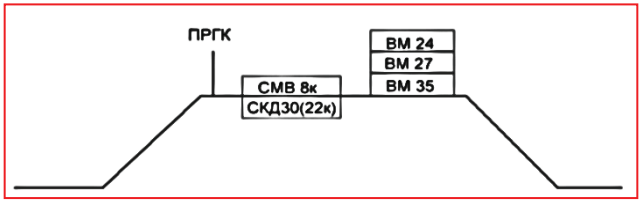
Extraction 50 GeV *p* (interference pRAD, 1-turn FE vs XPh)

Extraction 25 GeV/u *C*

- Issued extractions at low *N* qpp
- Bent crystal deflectors
  - New stations / beam traces [bending angles]
  - Complementary features 25 – 50 GeV
  - POP – no fragmentation of *C* beam
- Multi-user

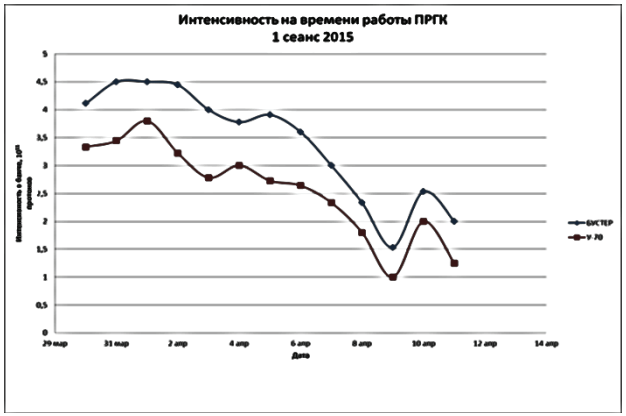
Multi-user

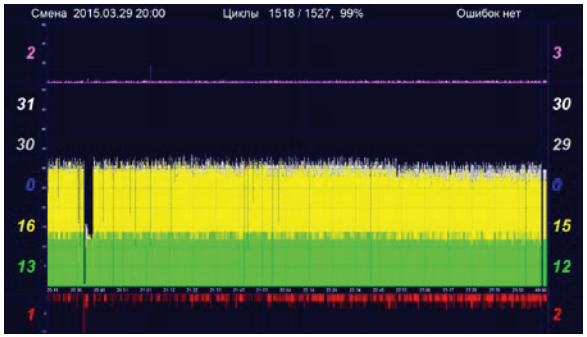


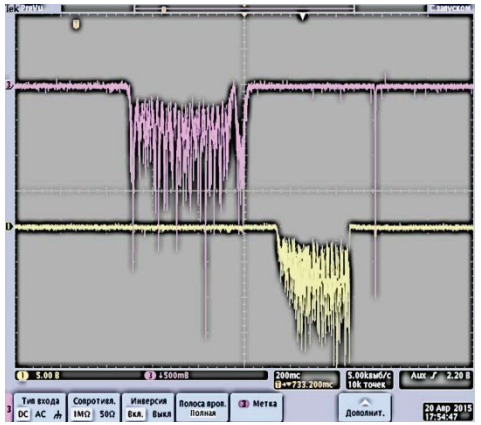


Run 2015-1. Positive trends

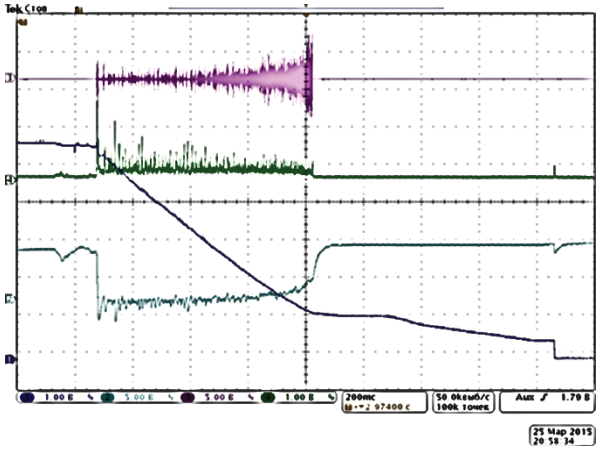
C (25 GeV/u):
СМВ+СКД27



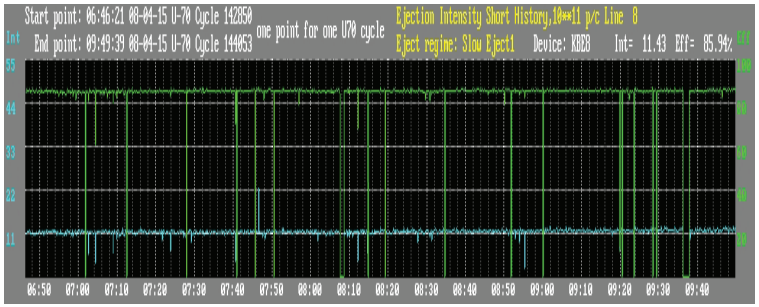




max 4.5 (U1.5) 3.8 (U70) $\cdot 10^{11}$ ppb



SSE out/in 80-83-90+ %

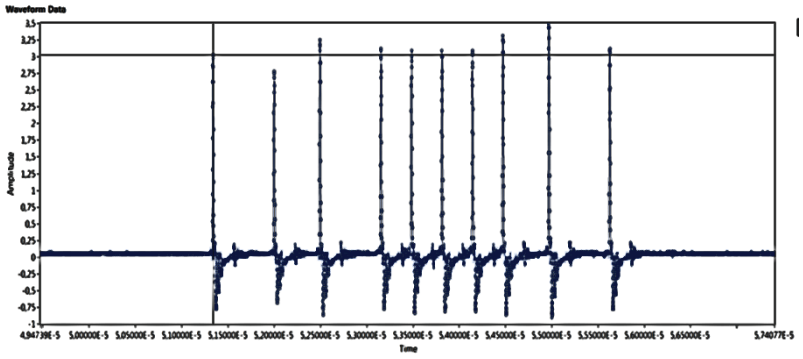


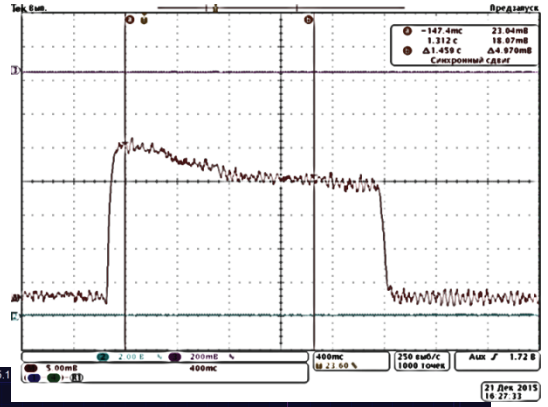
Run 2015-2. Statistics

User partition:
XPh1 | **pRAD** (BTL#22 МОЭ6) + [XPh-2] | XPh-3 | C | 455 MeV/u
Long “iterations” to settle schedule

50 GeV p	6-8 beam users
$3 \cdot 10^{12}$ ppp	(average)
$8.2 \cdot 10^{12}$ ppp	(max)
$5.3 \cdot 10^{12}$ ppp	(@91% max SSE)

456 MeV/u C	
U70	$3\text{-}5 \cdot 10^{9}$ ipp
Into BTL#25	$2\text{-}3 \cdot 10^{9}$ ipp
T cycle	8 s
Out/In SSE$t_{п}$	< 57%

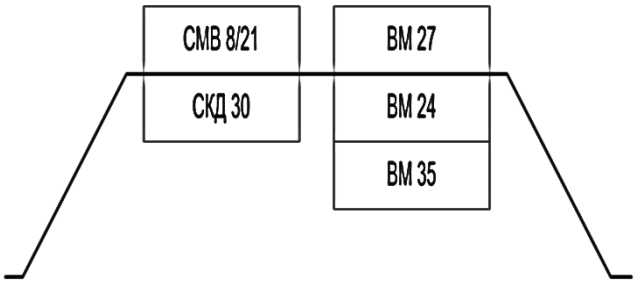


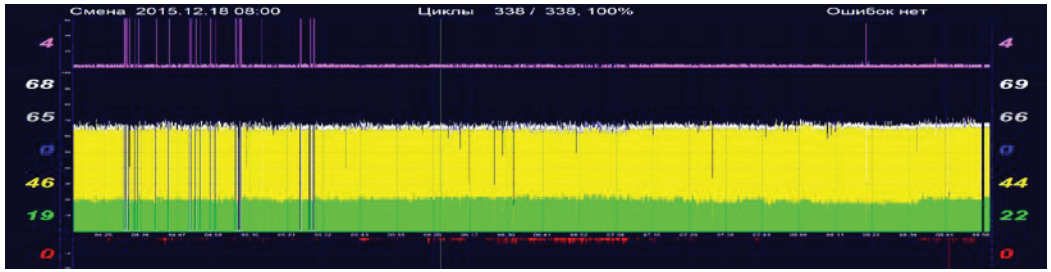


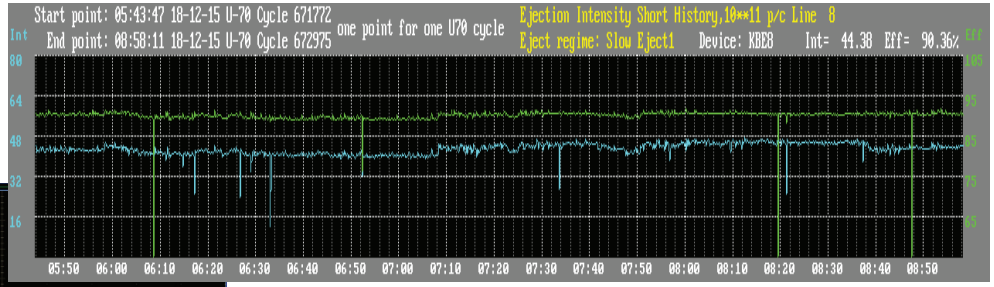
$4 \cdot 10^{9}$ ipp

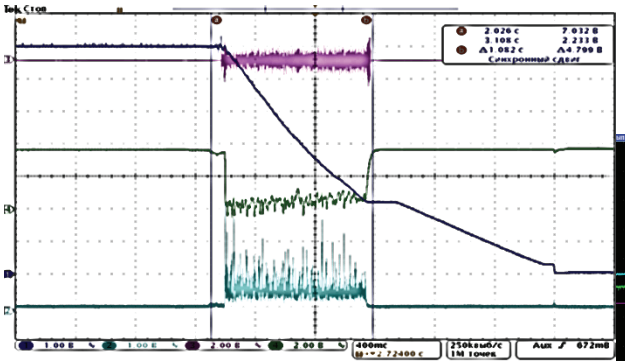
$3.4 \cdot 10^{12}$ ppp
in 10 bunches
November, 23 2015

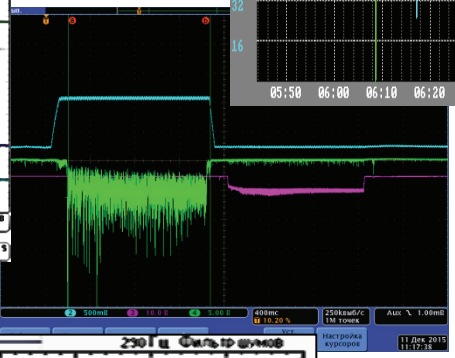
Run 2015-2. A few pictures



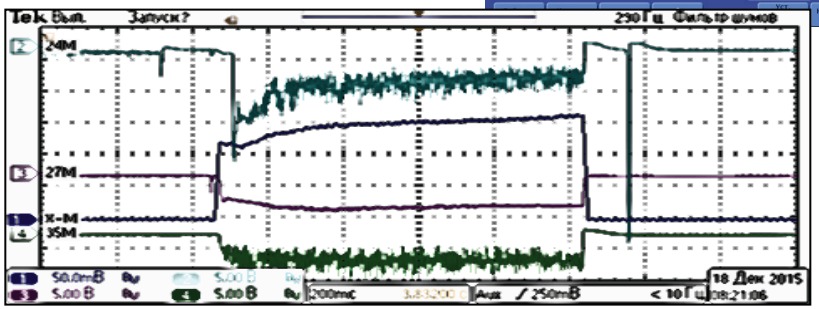








IT
#24
#27
#35



OFF at 9:00 December18, 2015

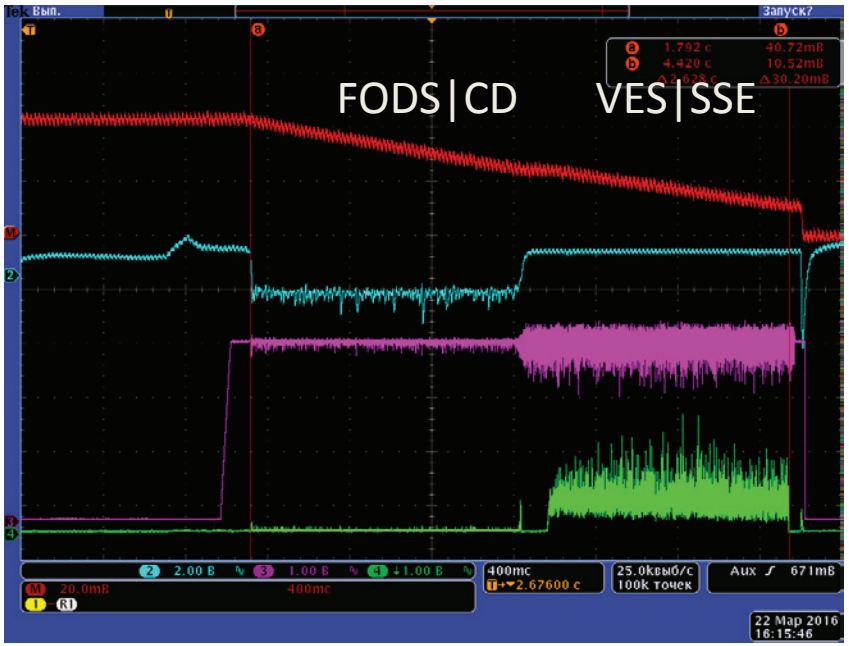
Run 2016-1. Specifics

40 GeV (*p*) pilot beam | 20 GeV/u (*C*) XPh (3 facilities via SSE and CD) |; 50 GeV (*p*) pRAD + XPh | 456 MeV/u (*C*)

Two species, **four** energies: p 40 and 50 GeV, C 20 GeV/u and 456 MeV/u

1st ever long-time carbon run for XPh in *high-energy* relativistic nuclear physics domain

10^5 to $4 \cdot 10^9$ nuclei per cycle (9.5 s)



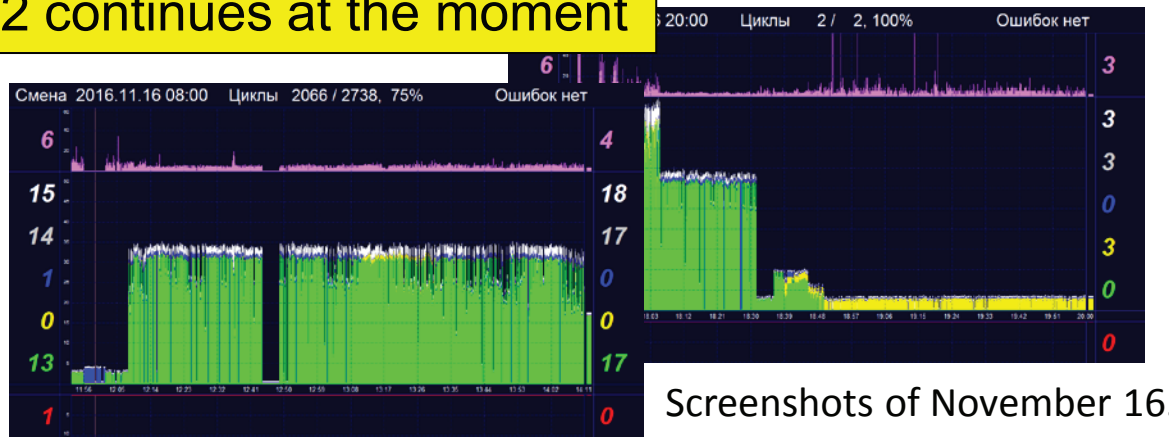
FODS	HE fragmentation vs fixed nuclei Secondary particles in a deep cumulative region
SPIN	Spectra of secondary's with large T-momenta Inversed kinematics in p-C & C-p interactions
VES	Meson states under C-C interactions Bounded meson-nuclei states

Conclusion

Accelerator Complex U70 at IHEP of NRC “Kurchatov Institute” is maintained in a healthy functional status, have noticeably improved its functionality due to recent upgrades and provides beams for ongoing topical fixed-target research both fundamental and applied,

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

Run 2016-2 continues at the moment



Screenshots of November 16. 2016