ITEP-TWAC renewal and upgrading program

N.N.Alexeev, P.N.Alekseev,V.A.Andreev,
A.N.Balabaev, A.I.Balabin, V.N.Balanutsa,
M.M.Kats, V.I.Nikolaev, A.S.Ryabtsev,
Yu.A.Satov, V.S.Stolbunov,V.A.Schegolev,
B.Yu.Sharkov, A.V.Shumshurov, V.P. Zavodov

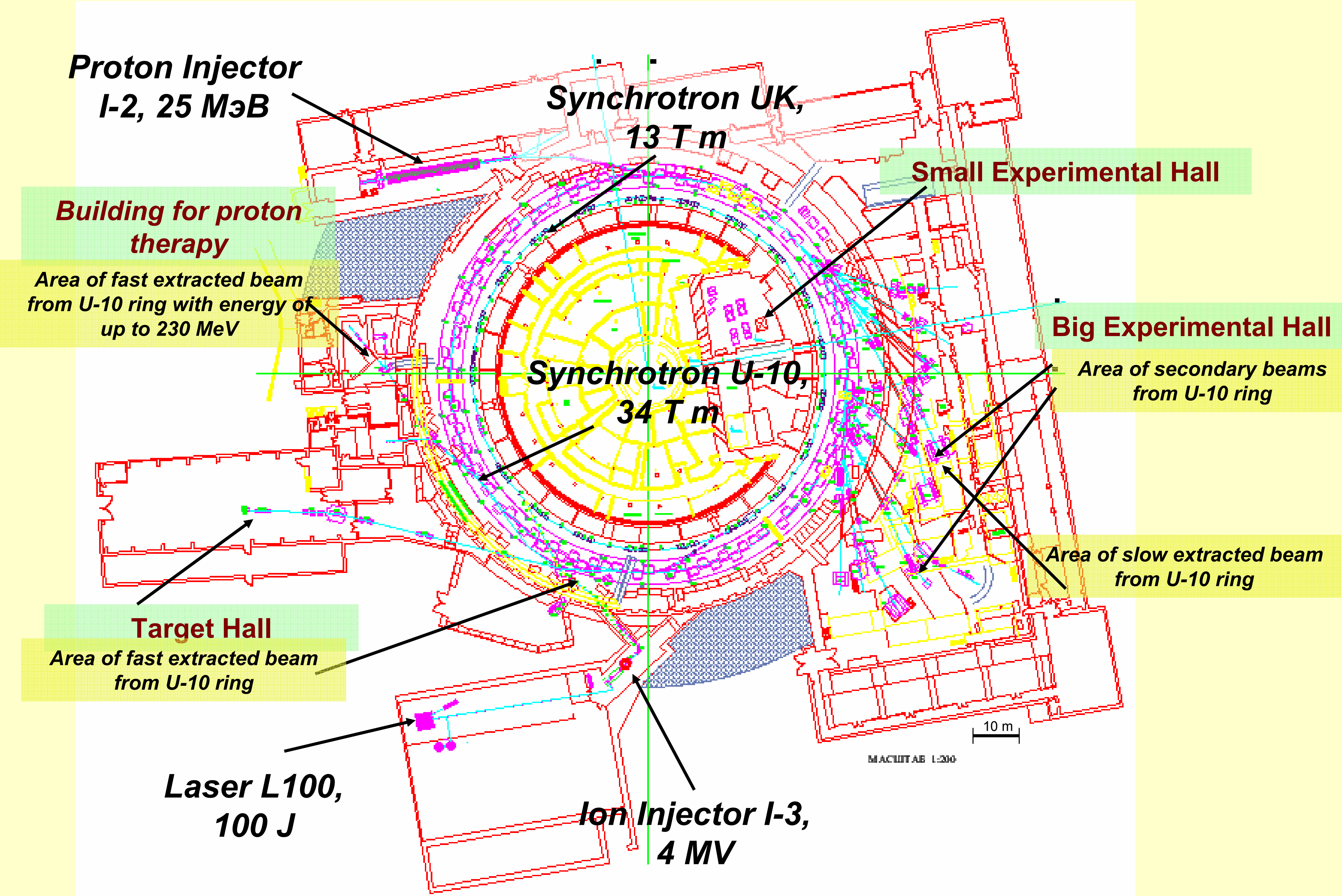
Institute for Theoretical and Experimental Physics
Moscow, Russia

RuPAC 2012

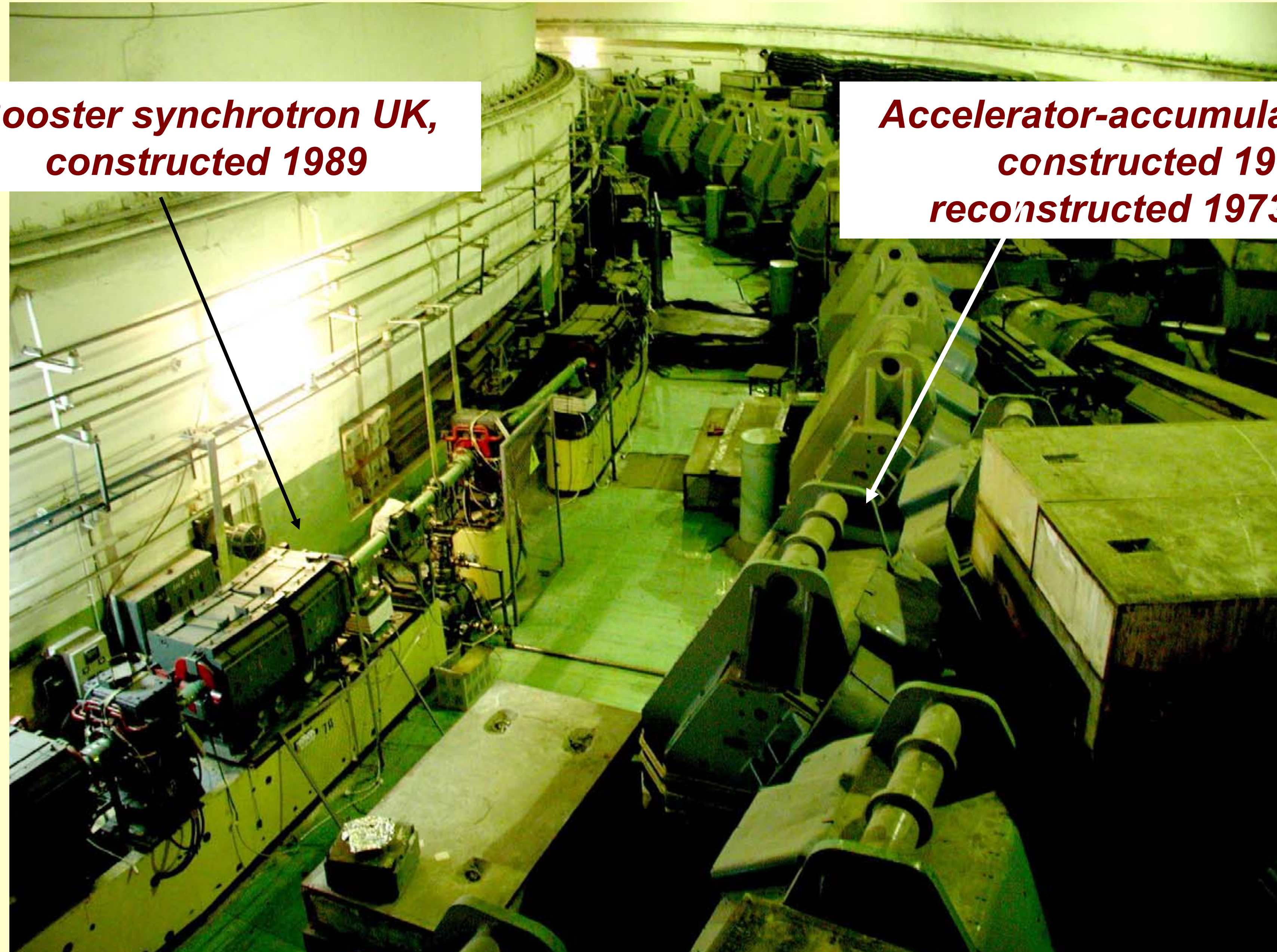
Content

- *Status of ITEP-TWAC in 2011*
- *Proposed conception of ITEP-TWAC renewal and upgrading*
    - *Injection Complex*
    - *Synchrotron UK*
    - *Accelerator-Accumulator U-10*
    - *Expanding of experimental area*
- *Schedule of machine renewal and upgrading*
- *Conclusion*

ITEP Accelerator Facility



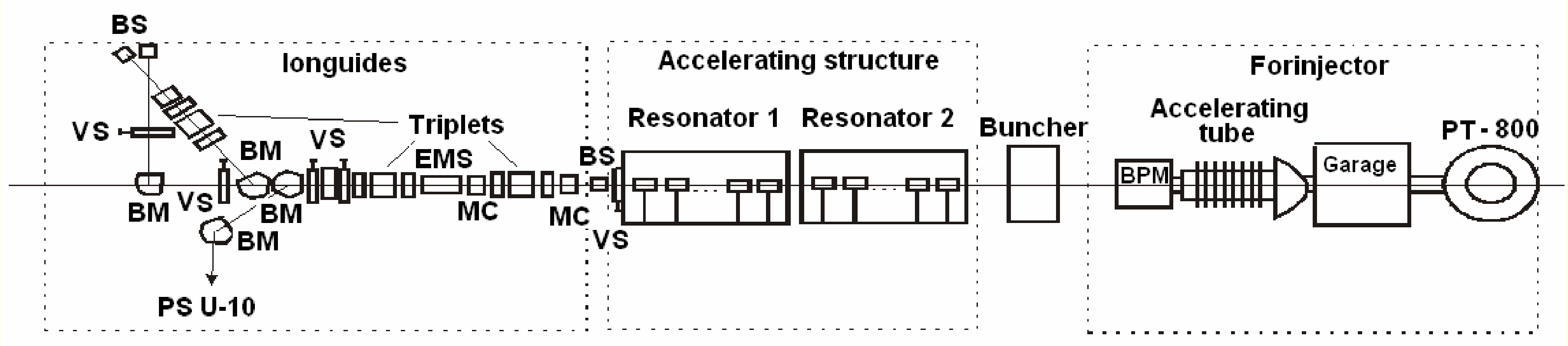
Ring magnets hall of ITEP-TWAC Facility



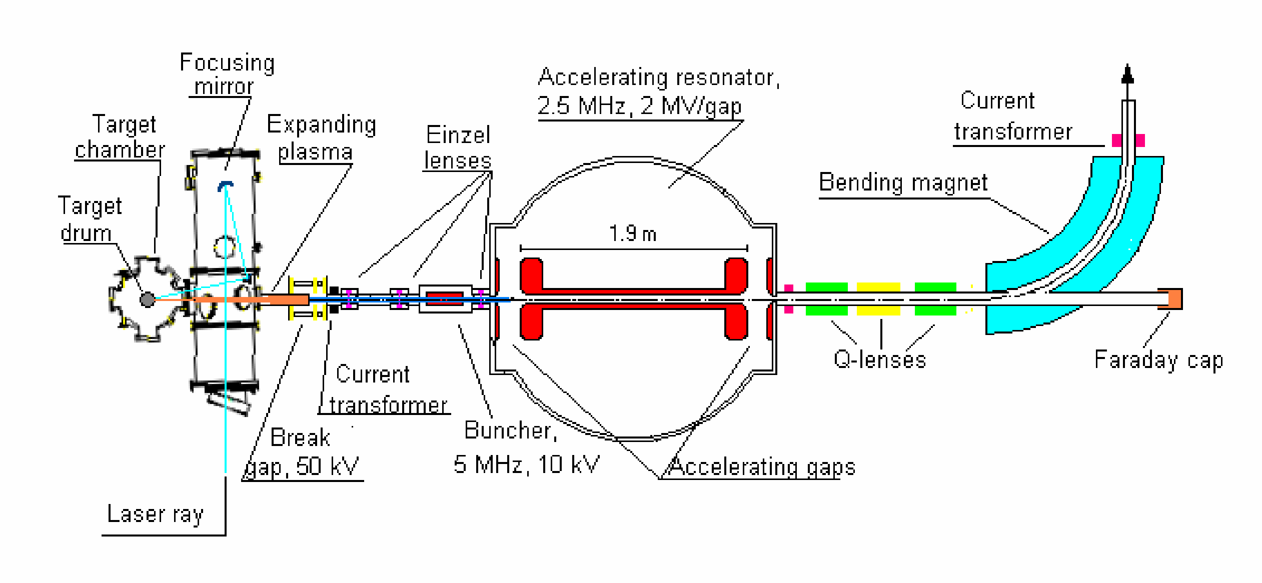
25 MeV/200 mA Proton Injector I-2 (1967)

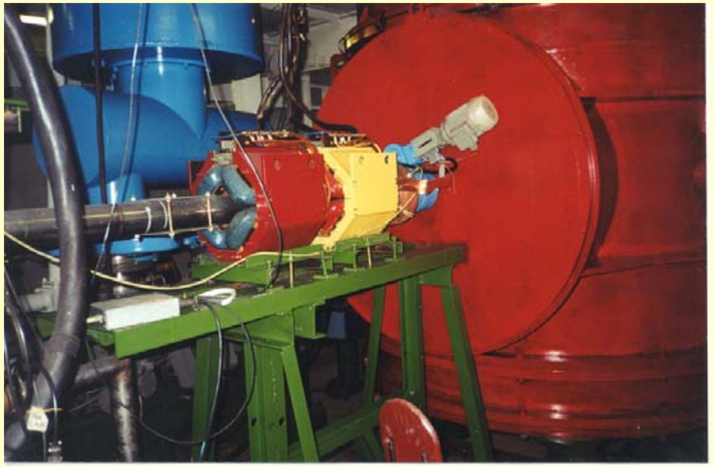
DC Accelerator

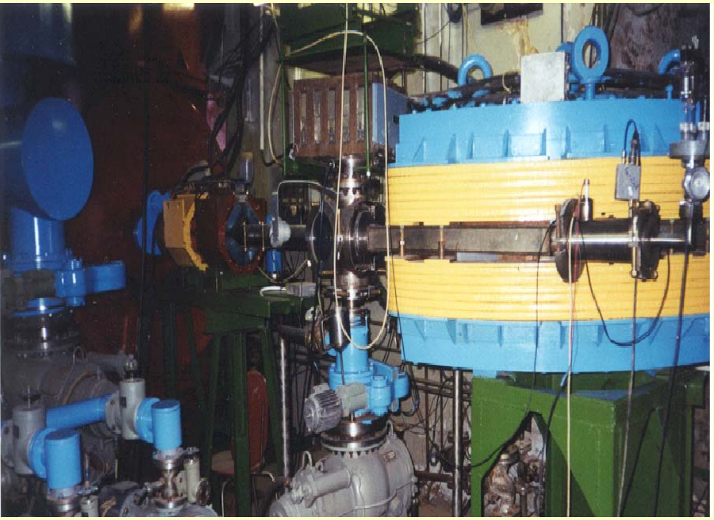
Tank with two resonators



Ion Injector I-3 (1998)







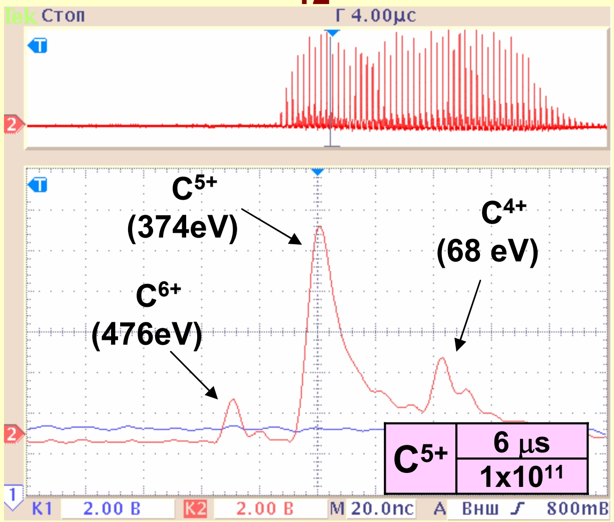
Accelerating frequency	**2,504 MHz**
Accelerating voltage	**up to 4 MV**
Bunching voltage	**up to 10 kV**
Accelerating ions, A/Z	**2-5**
Input beam energy	**50 kV**
Ion energy at A/Z=2÷5	**0,8-1,9 MeV/u**
Transverse acceptance	**2000 π·mm mrad**
Max output beam current	**7 mA (C^{4+})**

ITEP-TWAC Operation Parameters (2011)

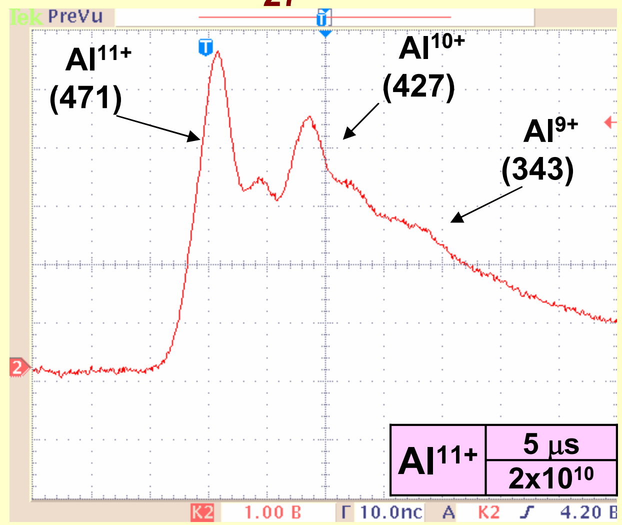
Mode of operation	Accelerators	Beam energy, MeV/u	Regime of beam extraction
Proton acceleration	*I-2* *I-2/U-10*	25 up to 230 up to 3000 up to 9300 up to 3000	pulse, 10 μ/s medical extraction, 200 ns, fast extraction, 800 ns, internal target, 1s slow extraction, 0.5 s
Ion acceleration, *C, Al, Si, Fe, Cu, Ag*	*I-3/UK* *I-3/UK/U-10*	1,5 – 400 up to 4000	fast extraction, 800 ns, *C(400 MeV/u, 2x10⁹), Al (265 MeV/u, 2x10⁸), Si (360 MeV/u, 1x10⁸), Fe (230 MeV/u, 2.5x10⁸), Ag (100 MeV/u, 2x10⁷),* internal target, 1s, fast (800 ns, 3 GeV/c) and slow extraction, (0.5 s, 3 GeV/c) *C(4 GeV/u, 5x10⁸), Al (4 GeV/u, 3x10⁷), Fe (3.6 GeV/u, 2x10⁷),*
Nuclei accumulation, *C, Al,Fe, Si*	*I-3/UK/U-10*	200-300	*C(300 MeV/u, 4x10¹⁰), Al (265 MeV/u, 3x10⁹), Si (240 MeV/u, 1x10⁹), Fe (230 MeV/u, 1x10⁹),* fast extraction with compression to 150 ns, continue extraction of stacking beam

Generation of ions in LIS with laser L100 (2011)

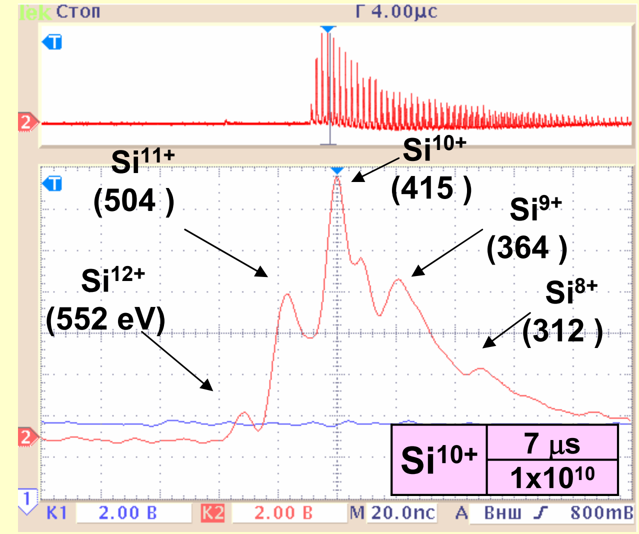
$_{12}C^{6+}$



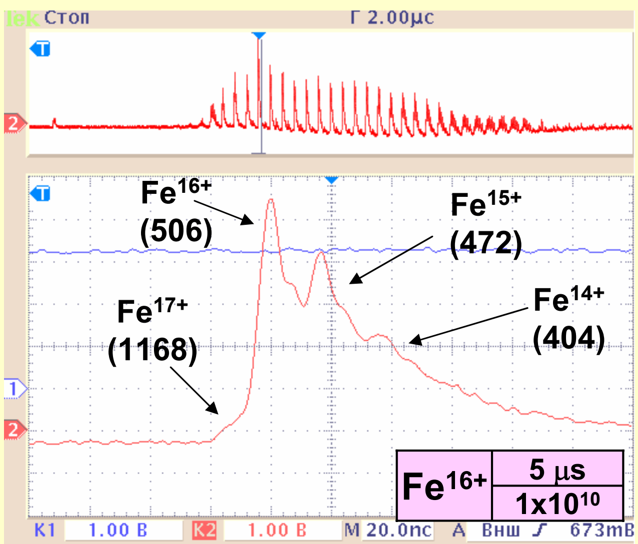
$_{27}Al^{13+}$



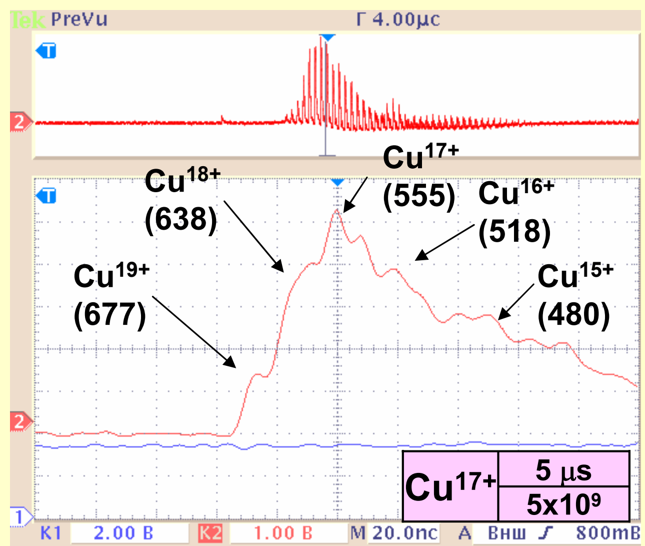
$_{28}Si^{14+}$



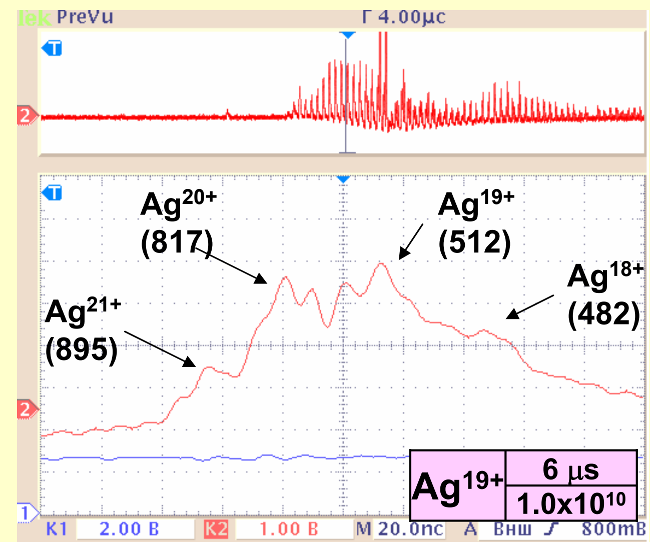
$_{56}Fe^{26+}$



$_{63}Cu^{29+}$

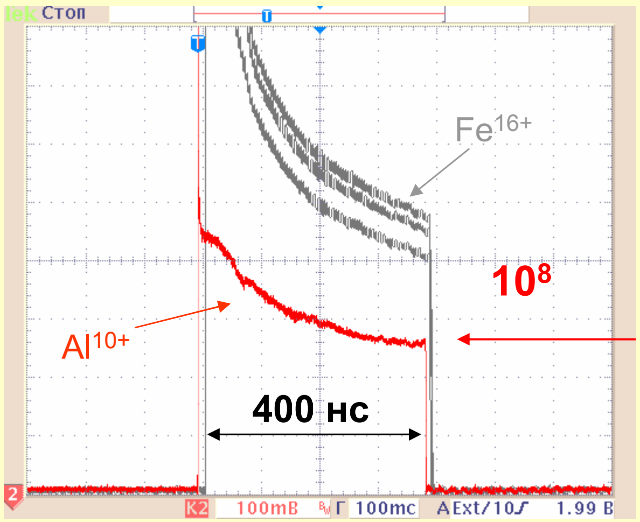


$_{109}Ag^{47+}$

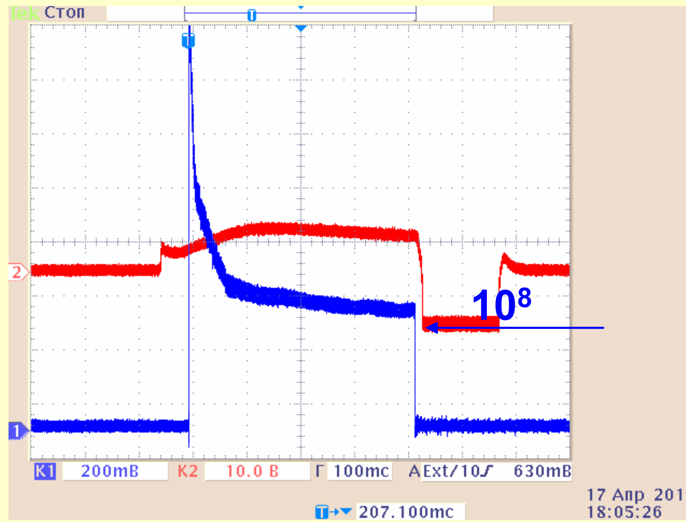


Acceleration of different ions in synchrotron UK

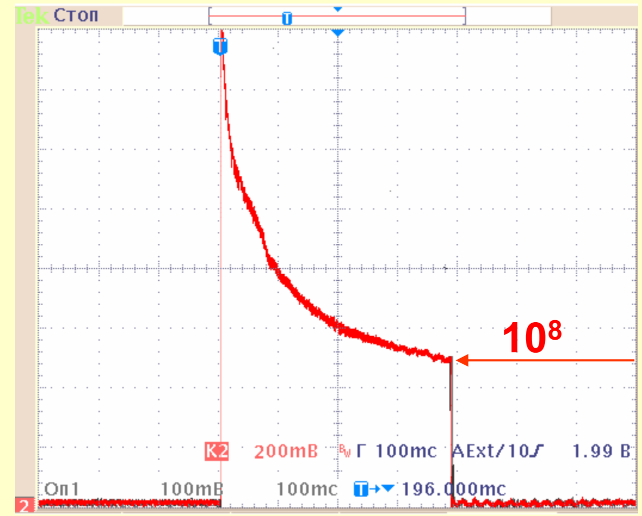
Acceleration of Al^{10+} up to energy 265 MeV/u



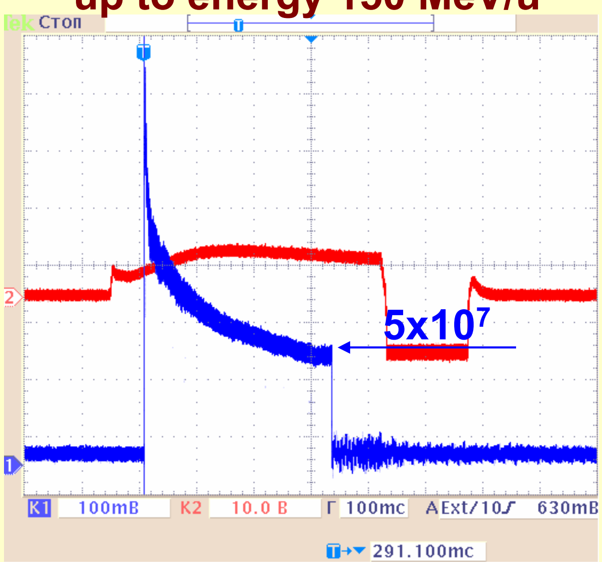
Acceleration of Si^{10+} up to energy 360 MeV/u



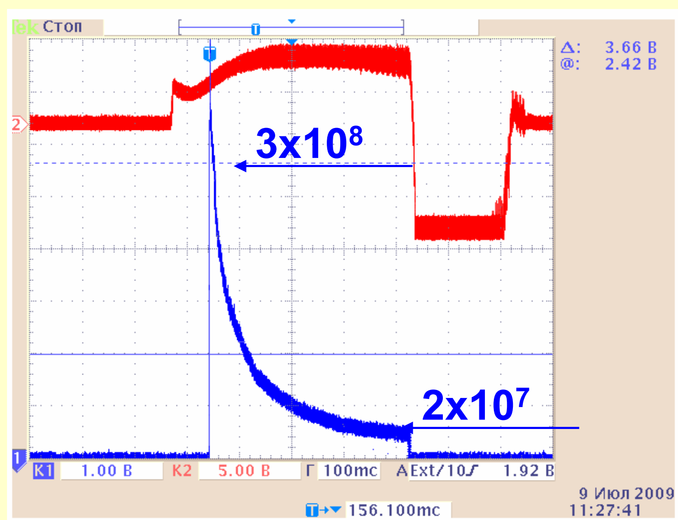
Acceleration of Fe^{16+} up to energy 230 MeV/u

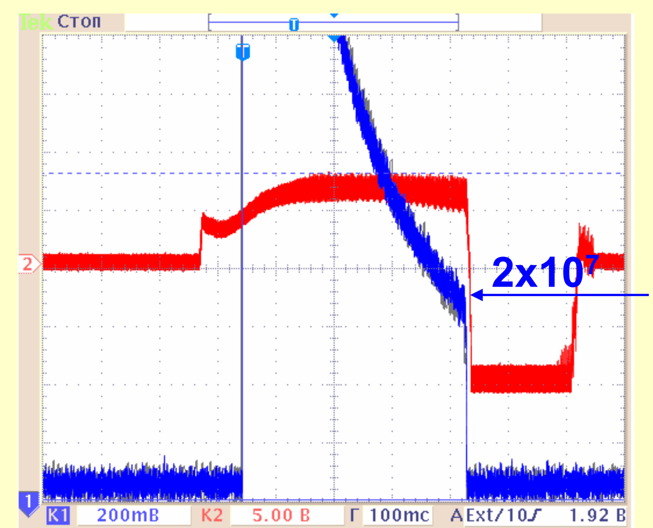


Acceleration of Cu^{17+} up to energy 150 MeV/u



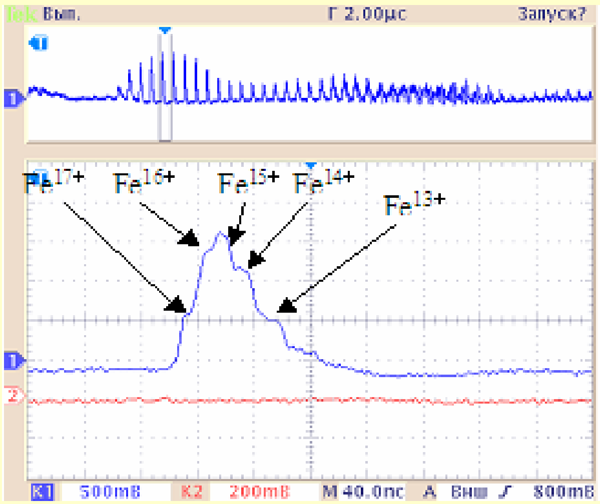
Acceleration of Ag^{19+} up to energy 100 MeV/u



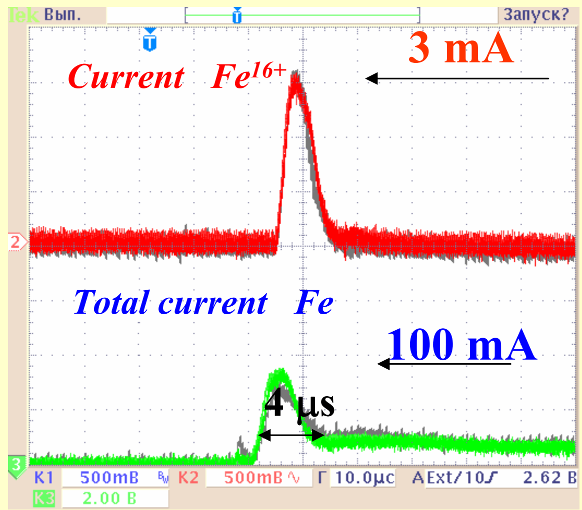


Acceleration of nuclei Fe in I-3/UK/U-10 up to relativistic energy (2009)

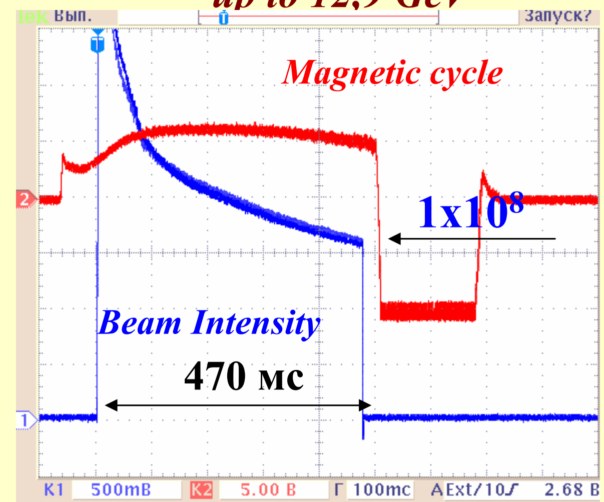
Generation of $_{56}$Fe ion in LIS100



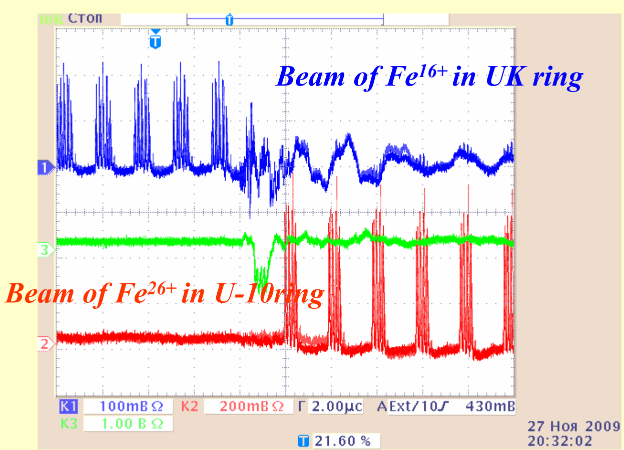
Acceleration of Fe^{16+} in I-3 linac



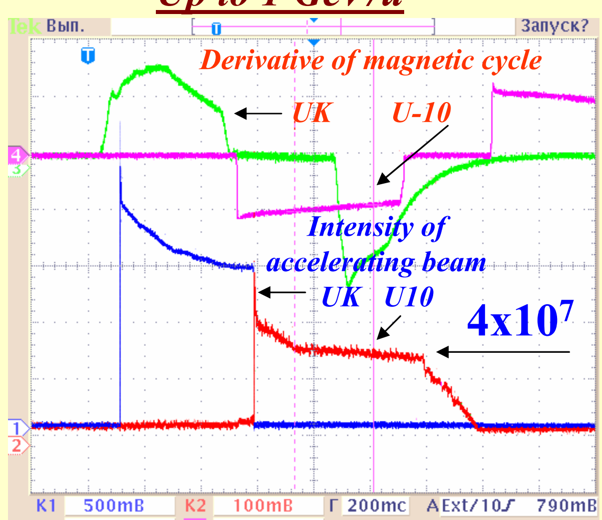
Acceleration of Fe^{16+} in UK Ring up to 12,9 GeV



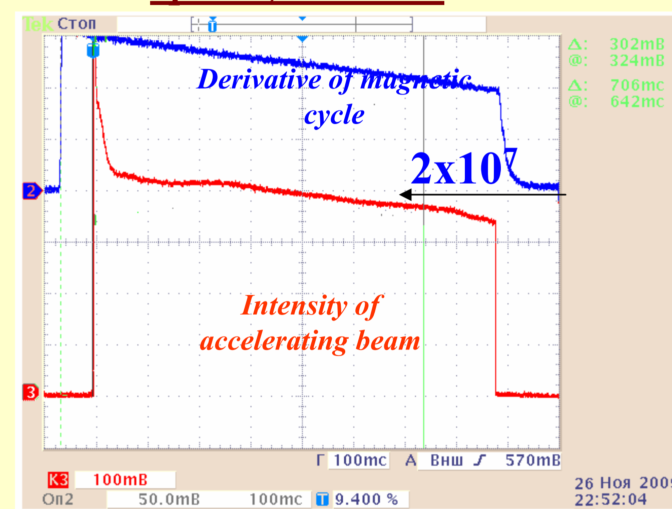
Charge exchange injection of $_{56}$Fe from UK to U-10



Acceleration of Fe^{26+} in U-10 Up to 1 GeV/u



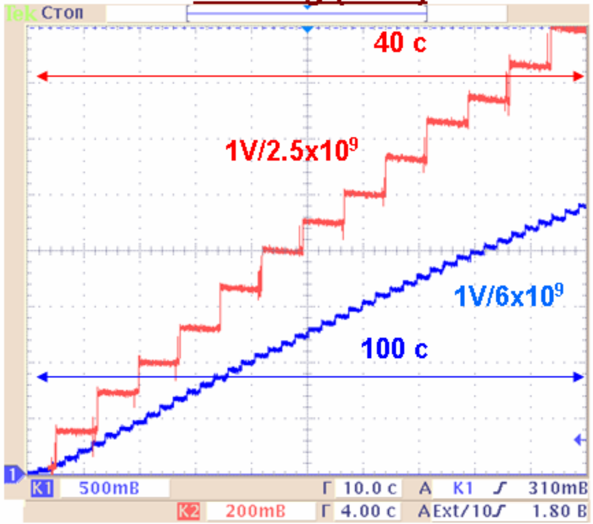
Acceleration of Fe^{26+} in U-10 up to 3,65 GeV/u



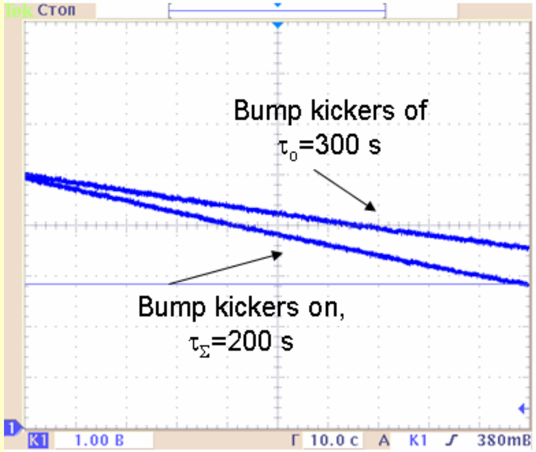
Carbon nuclei stacking in U-10 Ring (2006)

Energy	300 MeV/u
Intensity of injecting beam	$6x10^8$
Repetition rate, s	3
Acceptance, A_x, π mm mrad	10
Vacuum, Torr	$\sim 1x10^8$
Stacking factor	~70
Intensity of stacked beam	$4x10^{10}$

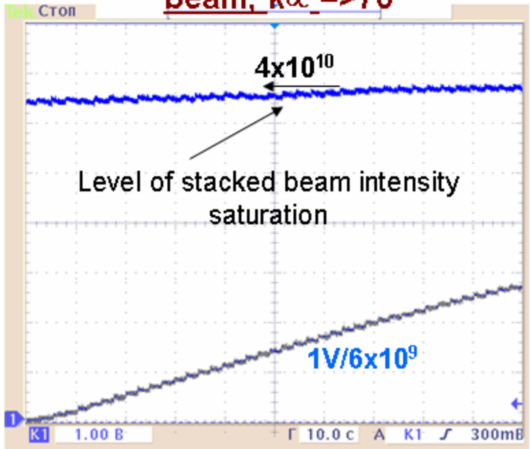
The stairs of C^{6+}-beam stacking in the U10 ring (2006)



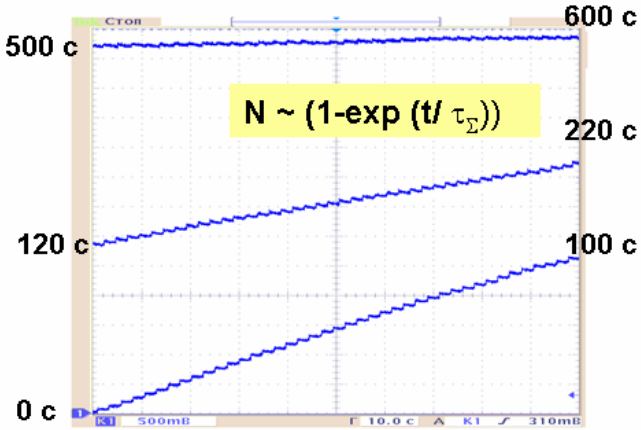
Stacked beam life time in the U-10 Ring



Maximal intensity of stacked beam, k∝ =>70



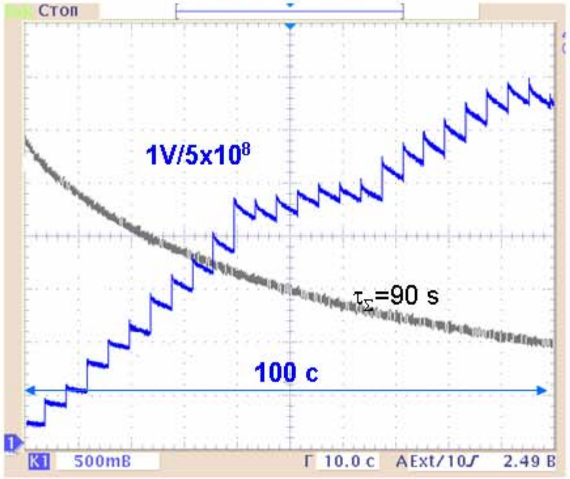
Intensity increase in time



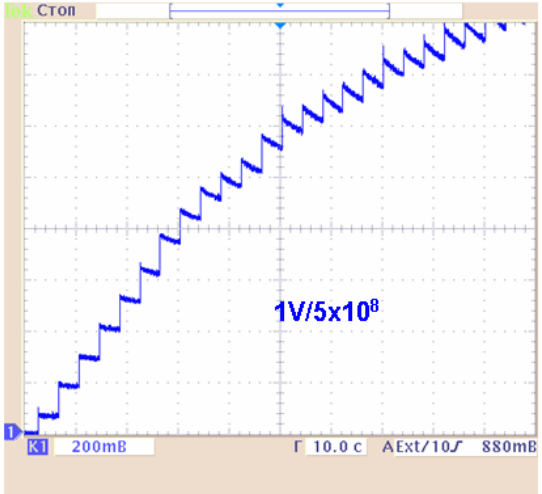
Stacking of nuclei: Al, Si, Fe (2011)

	Al	Si	Fe
Energy, MeV/u	265	240	230
Intensity of injecting beam	~$1x10^8$	~$5x10^7$	~$1x10^8$
Repetition rate, s		4	
Acceptance, A_x, π mm mrad		10	
Vacuum, Torr		~$1x10^8$	
Stacking factor	~30	~ 20	~10
Intensity of stacked beam	~$3x10^9$	~$1x10^9$	~ $1x10^9$

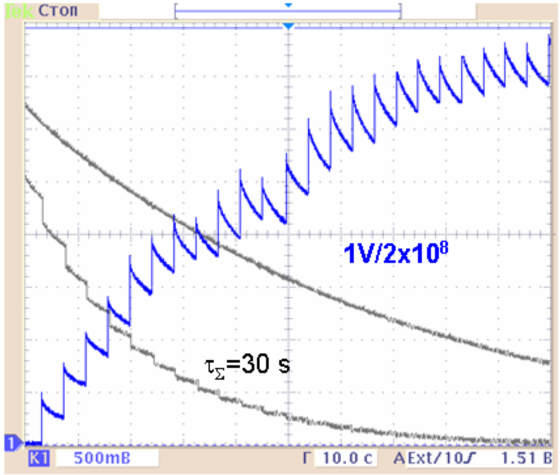
Al^{10+}=>Al^{13+}



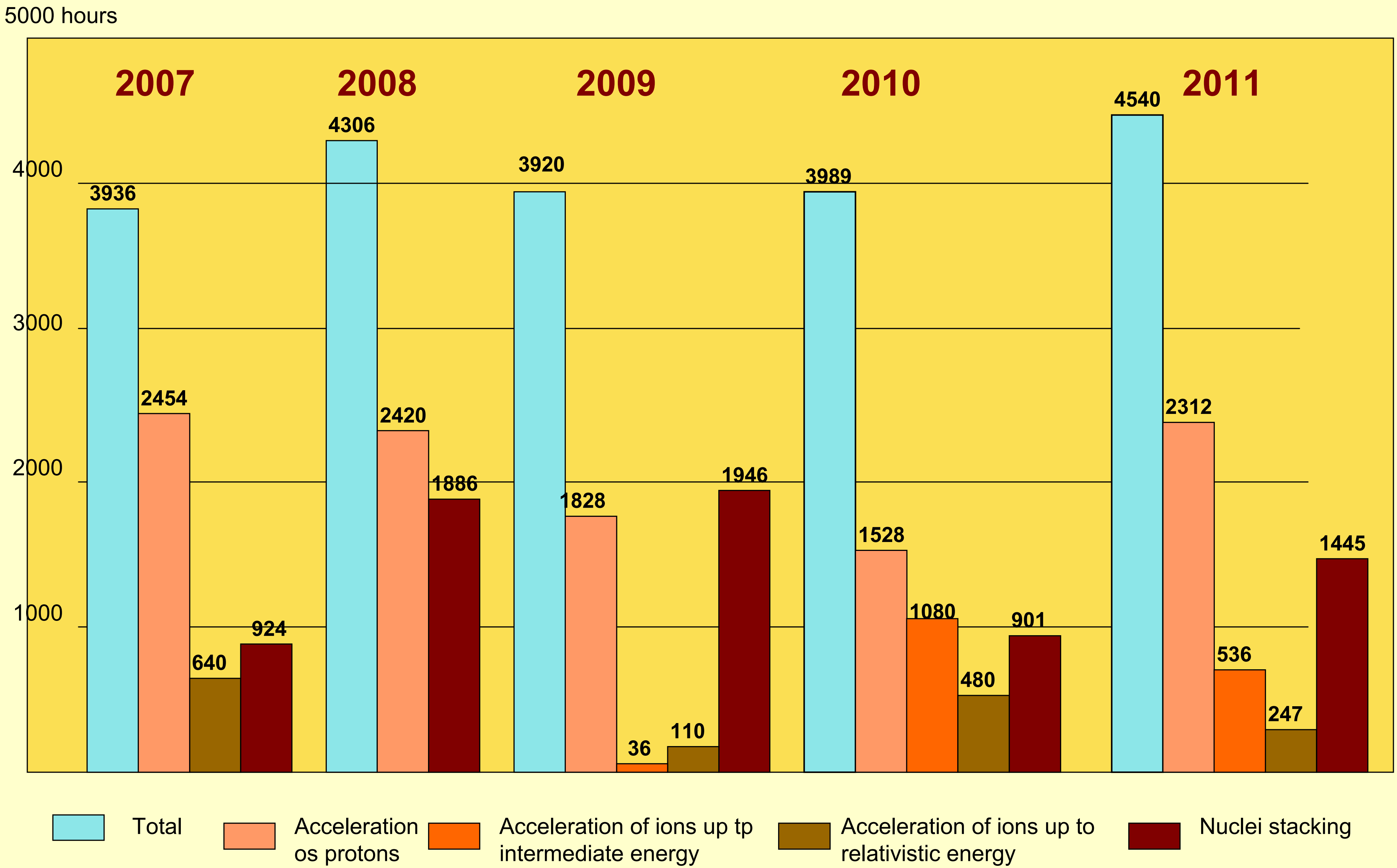
Si^{10+}=>Si^{14+}



Fe^{16+}=>Fe^{26+}



Statistic of ITEP-TWAC operation



Accelerator operation time for different research fields

Research fields with proton and ion beams	Beams	Beam time, (hours)		
		2009	2010	2011
Relativistic nuclear physics	p (2-9 ГэВ, 10^{11}с$^{-1}$) C,Al …(4 ГэВ/н, 10^{8}с$^{-1}$)	1100	850	702
Methodical research	p (1-9 ГэВ, 10^{11}с$^{-1}$) C(0,2-4 ГэВ/н, 10^{8}с$^{-1}$)	2100	2045	2450
Physics of high density energy in matter	C, Al,Fe…, (200-300 МэВ/н, 4x10^{10}с$^{-1}$)	350	330	288
Radiobiology and medical physics	p (250 МэВ, 10^{11}с$^{-1}$) C (200-300 МэВ/н, 10^{9} с$^{-1}$)	2150	2040	2320
Proton therapy	p (250 МэВ, 10^{11}с$^{-1}$)			
Radiation treatment of materials	p (20-400 МэВ, 10^{11}с$^{-1}$) Fe, Ag (40-200 МэВ/н, 10^{8} с$^{-1}$)	1100	550	779
Total		6800	5815	6539

Proposed conception of ITEP-TWAC renewal

1. **Renewal of multipurpose proton-ion accelerator and nuclei accumulator facility ITEP-TWAC for:**

   - fundamental and applied research with relativistic proton and ion beams in the energy range from 1 GeV/u up to 10 GeV for protons and 4 GeV/u for ions;

   - applied research with proton and ion beams in the energy range from 10 MeV/u up to 1000 MeV/u in industry, biology and medicine;

   - fundamental and technological research with high power stacked nuclei beams of particles with atomic number up to ~60 in the energy range of ~1 GeV/u;

   - technological research for high charge state and high intensity heavy ion beam generation, acceleration, accumulation, compression, extraction and sharp focusing;

   - expansion of scientific and educational activity on the subject of nuclear technologies**.**

Proposed conception of ITEP-TWAC upgrading

2. Upgrading of relevant ITEP-TWAC systems for:

- *extending of accelerated ions composition up to A ~ 200;*
- *cardinal increasing of intensity for accelerated ion beams in UK Ring on a base of ion injector and synchrotron upgrading;*
- *cardinal increasing of intensity for stacked nuclei beams in U-10 Ring on a base of charge exchange injection technology improvement;*
- *expansion and development of machine experimental area;*
- *mastering of multimode machine operation in parallel with proton and ion beams for maximal efficiency.*

Upgrade of Injection Complex

1. **Laser Ion Source:**

   - optimization of LIS optical scheme with replacement of some optical elements for cardinal increase of radiation power density on the target surface

2. **Ion injector I-3 {A/Z=(2÷5), 4MV, 5mA }:**

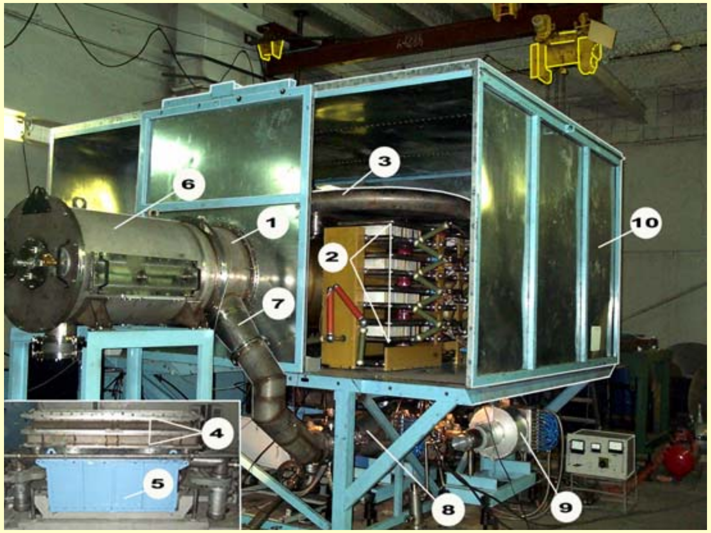
   - modification to I-3M for {A/Z=(3÷10), ~12MV, ~10mA, 5 μ s)

3. **Construction of new Injector I-4 for acceleration of light ions**

   A/Z=3, (4.8_{RFQ}+ 15.3_{DTL})MV, ~100mA

Configuration of LIS (2008)

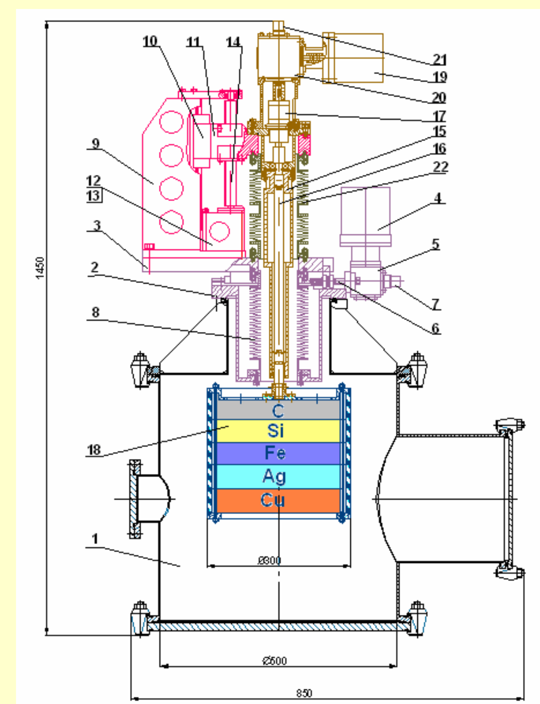
Laser L100 layout



Laser ray transfer line

Target station

Changing of the target material

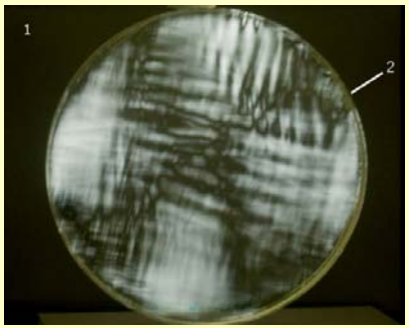


Project LIS Parameters

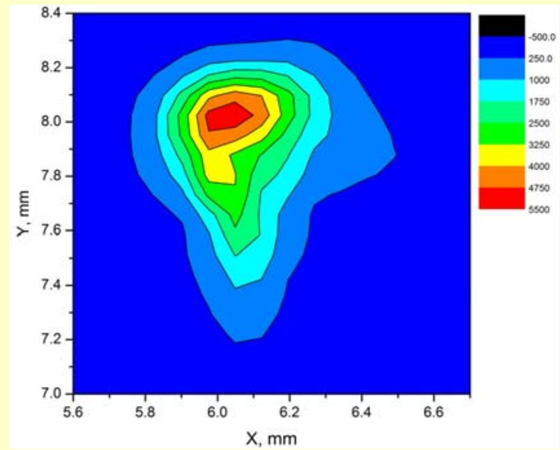
Wavelength, μ	**10,6**
Pulse energy, J	**5/20/100**
Pulse duration, ns	**100/80/30**
Power density at target spot	~10^{13} W/cm^2
Max. repetition rate, Hz	**0,5 /1/1**
Operational resource	**~10^6**

Studying of LIS optical channel elements

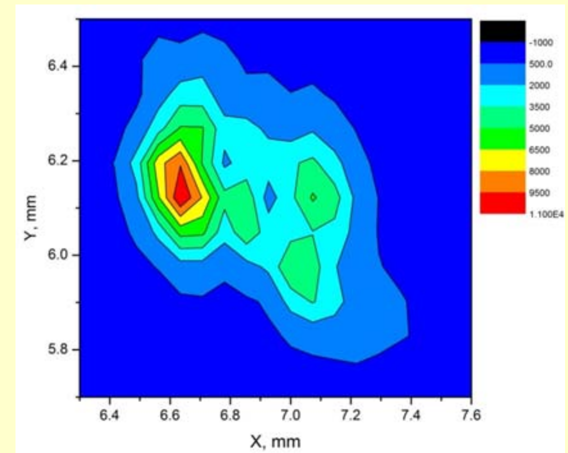
The power density of laser radiation on the LIS target surface has been limited on the level of $5x10^{11}$ - 10^{12} W/cm^2 by serious imperfections of some optical elements (spherical mirror and inlet window of target station) in the laser radiation transfer channel and by using off-axis focusing of laser ray on the target surface.



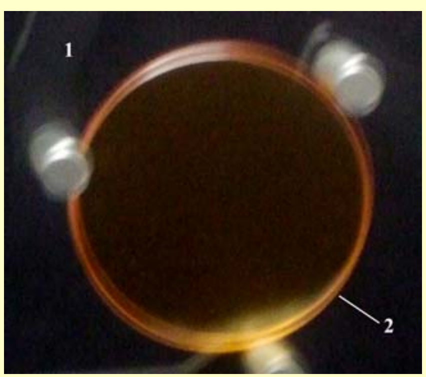
Results of optical homogeneity scanning for typical windows sample fabricated of potassium chloride monocrystal



Laser radiation distribution on the surface of LIS target



Laser radiation distribution on the focal plane for axial symmetric optic



Results of optical homogeneity scanning for typical windows sample fabricated of zinc selenide monocrystal

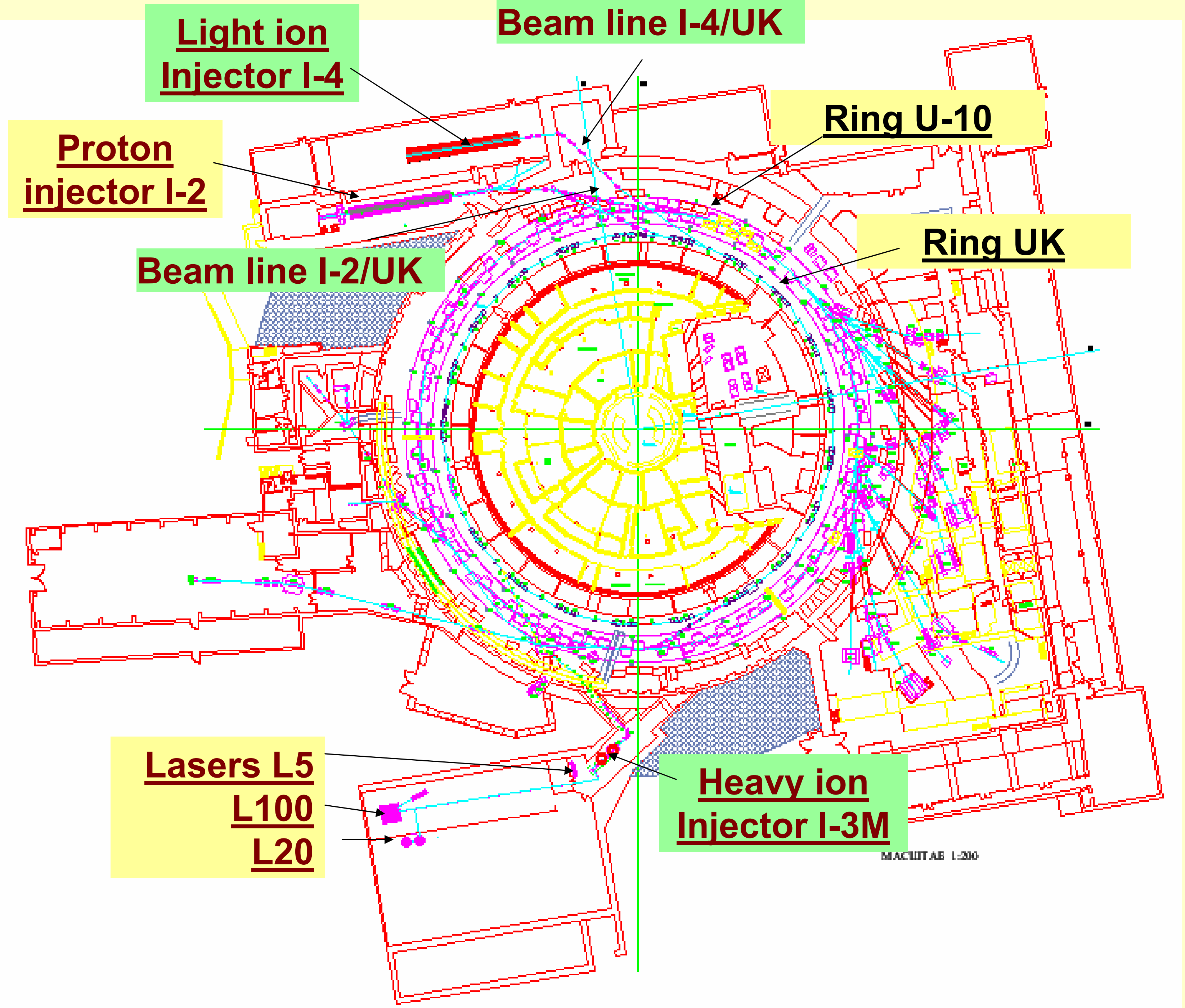
Image of a point radiation source transmitted by damaged mirror in optical telescop

Ion generation in LIS with optimized optical channel (expected)

Adequate substitution of defective elements of the channel and implementing of new LIS target station which is now under construction with central focusing of laser ray on the target surface have to increase the power density of laser radiation on the LIS target surface up to the value of 10^{13} - 10^{14} W/cm^2 .

Ion	$U^{(24 \div 30)+}$	$Bi^{(21 \div 29)+}$	$Au^{(21 \div 29)+}$	$W^{(21 \div 28)+}$	$Ag^{(19 \div 22)+}$	$Mo^{(16 \div 22)+}$	$Ge^{(15 \div 22)+}$	$Ni^{(17 \div 18)+}$
Z_0	92	83	79	74	47	42	32	28
A	238	209	197	182	107	96	73	59
U_{ion}	600÷966	548÷994	545÷986	571÷893	512÷974	571÷968	559÷917	587÷624
A/Z	9.9÷7.9	10÷7.2	9.4÷6.8	8.7÷6.5	5.6÷4.9	6÷4.4	4.9÷3.3	3.5÷3.3

Upgrade of ITEP-TWAC Injection Complex

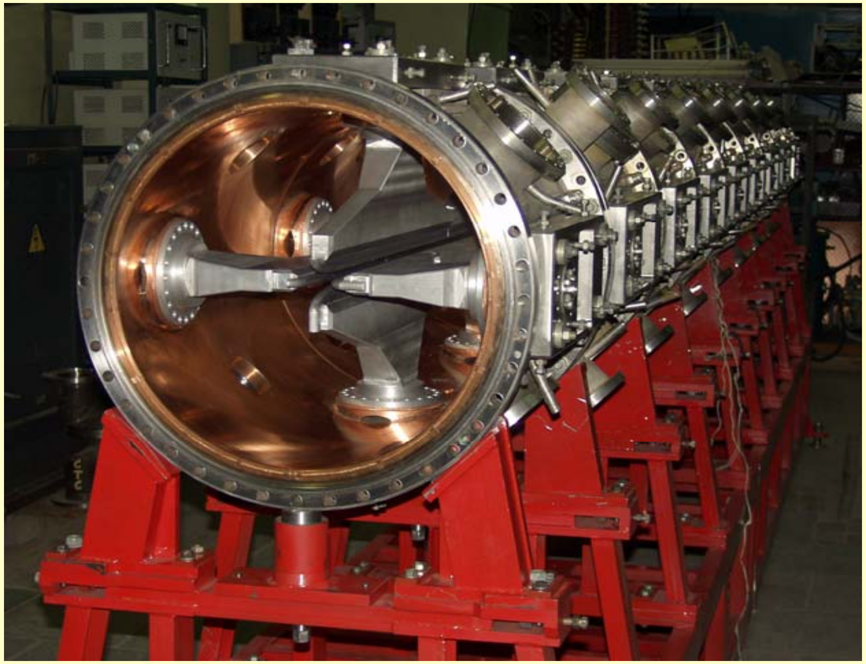


Light ion injector I-4

Parameters

RF-linac (~80 MHz)
Energy - 5÷7 MeV/u
Z/A ~ 1/3
Imax ~100 mA

1,6 MeV/u RFQ resonator

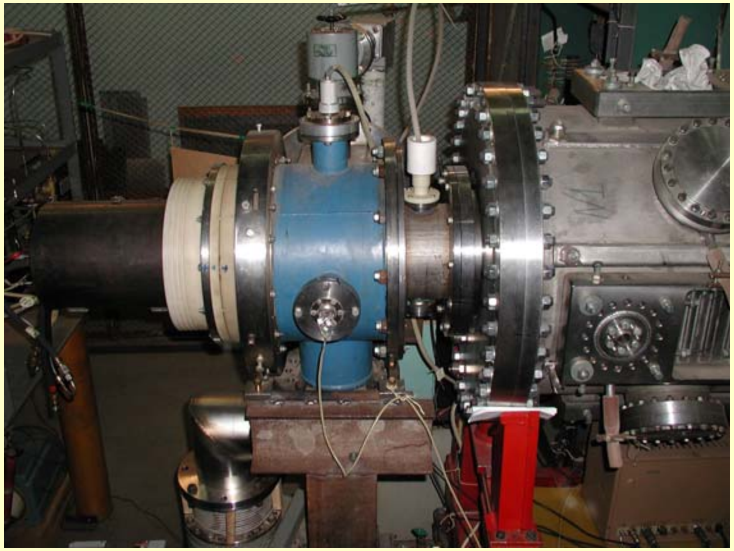


RFQ Section

Parameter	Unit	Value
Operating frequency	MHz	81.5
Charge to mass ratio		1/3
Input/output energy	MeV/u	0.02/1.57
Average radius	mm	10
Vane tip radius	mm	7.5
Voltage	kV	182.5
Input emittance (norm)	cm*mrad	0.327
Output emittance (effective)	mm*mrad	2.3*π
Input current	mA	100
Pulse repetition	Hz	1
Pulse duration	μs	100
Output energy spread	keV/u	+/- 20
Length of the RFQ vanes	m	6.258
Inner cavity diameter	m	0.564
Quality factor of the resonator		11000

Stand testing of RFQ Section

Ion source



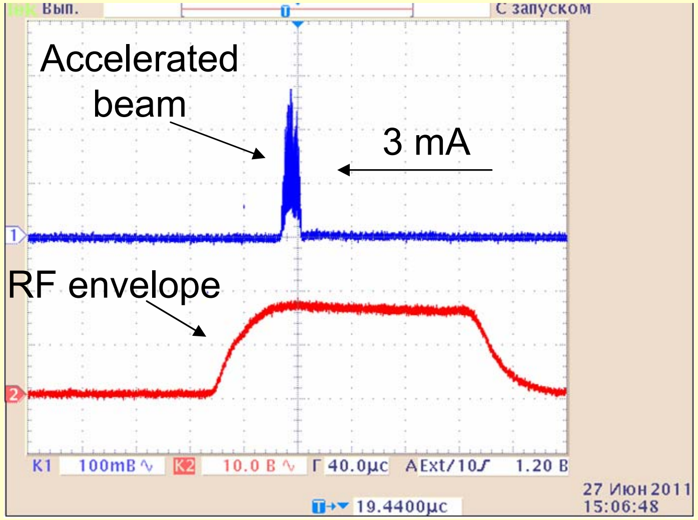
General view of RFQ section

RF generator

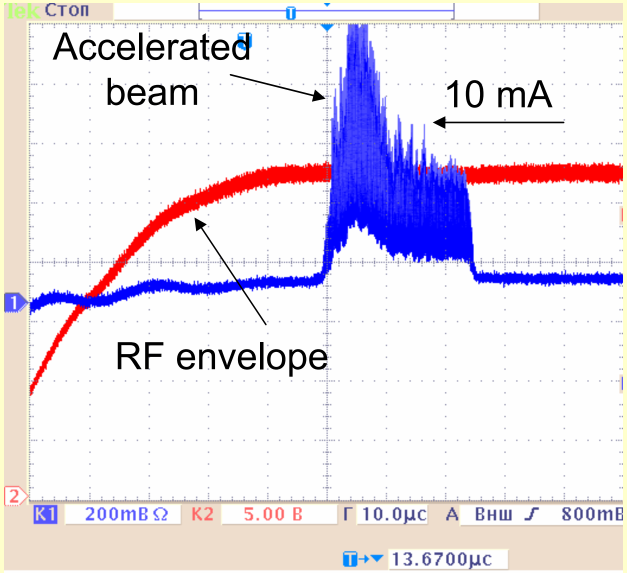
Top view

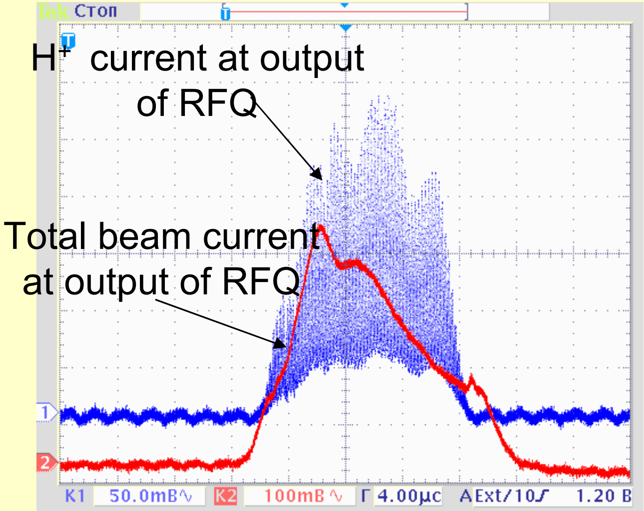
Beam test of RFQ section

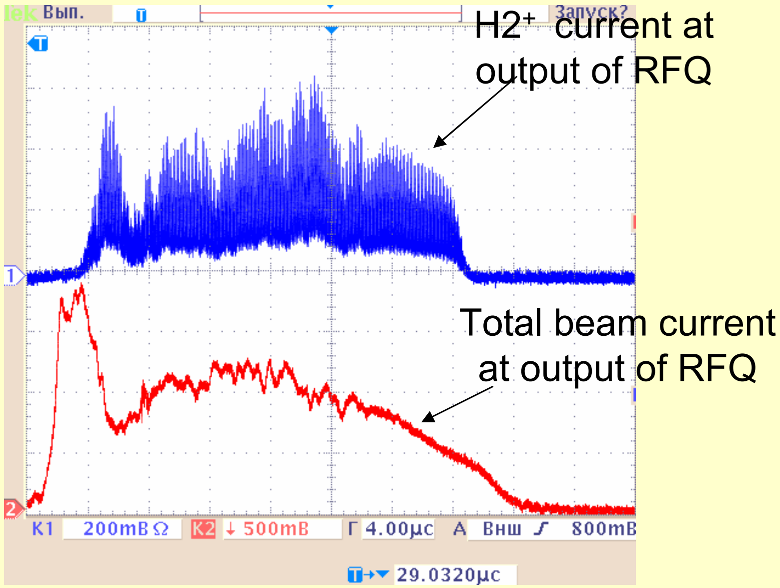
Acceleration of H^+ up to energy of 1,6 MeV



Acceleration of $H2^+$ up to energy of 3,2 MeV

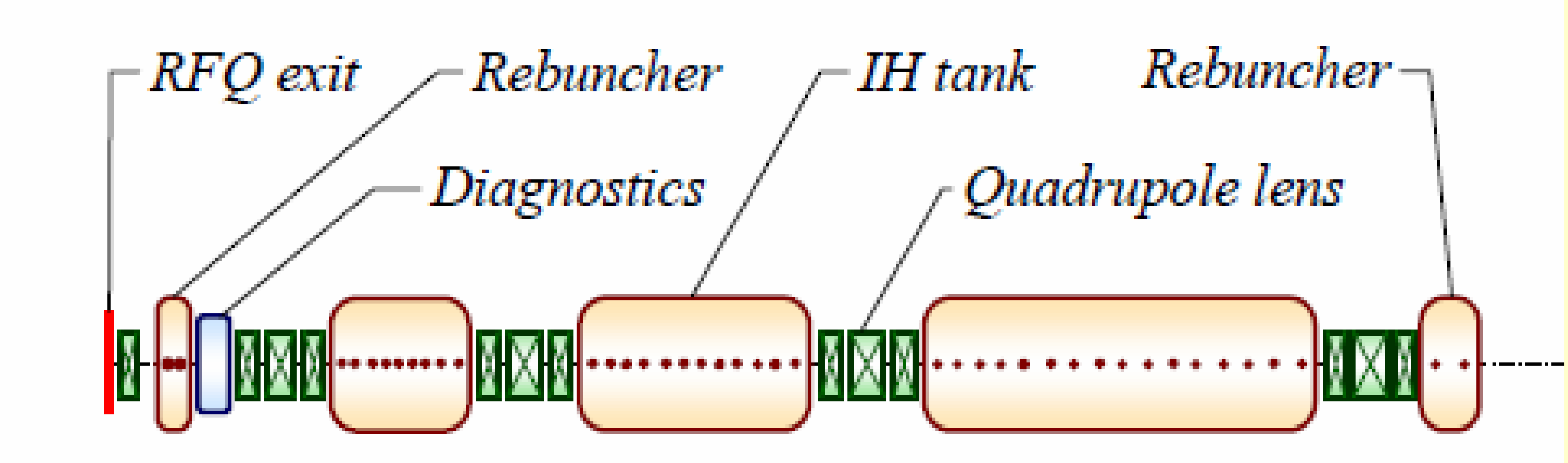






Option 1. DTL based on H Cavity with Magnetic Quadruple focusing between Cavities

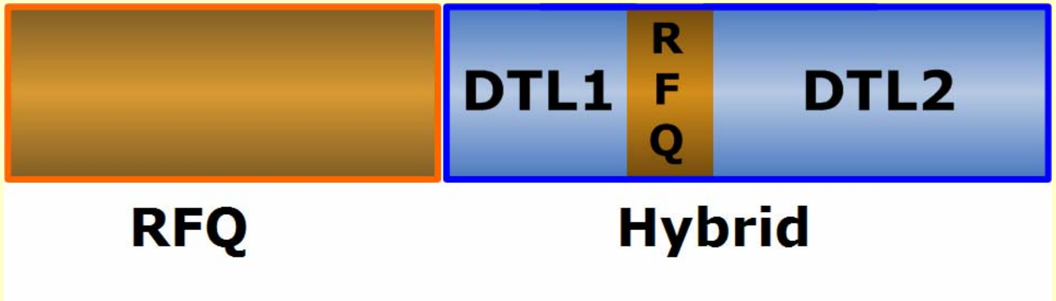
Proposed by Sergei Minaev



	Cavity 1	Cavity 2	Cavity 3
Voltage, kV	600	600	600
Number of gaps	10	11	11
Length, mm	650	928	1093
Gap length, mm	28	28	28
Output energy, MeV/u	3.28	5.19	7.11

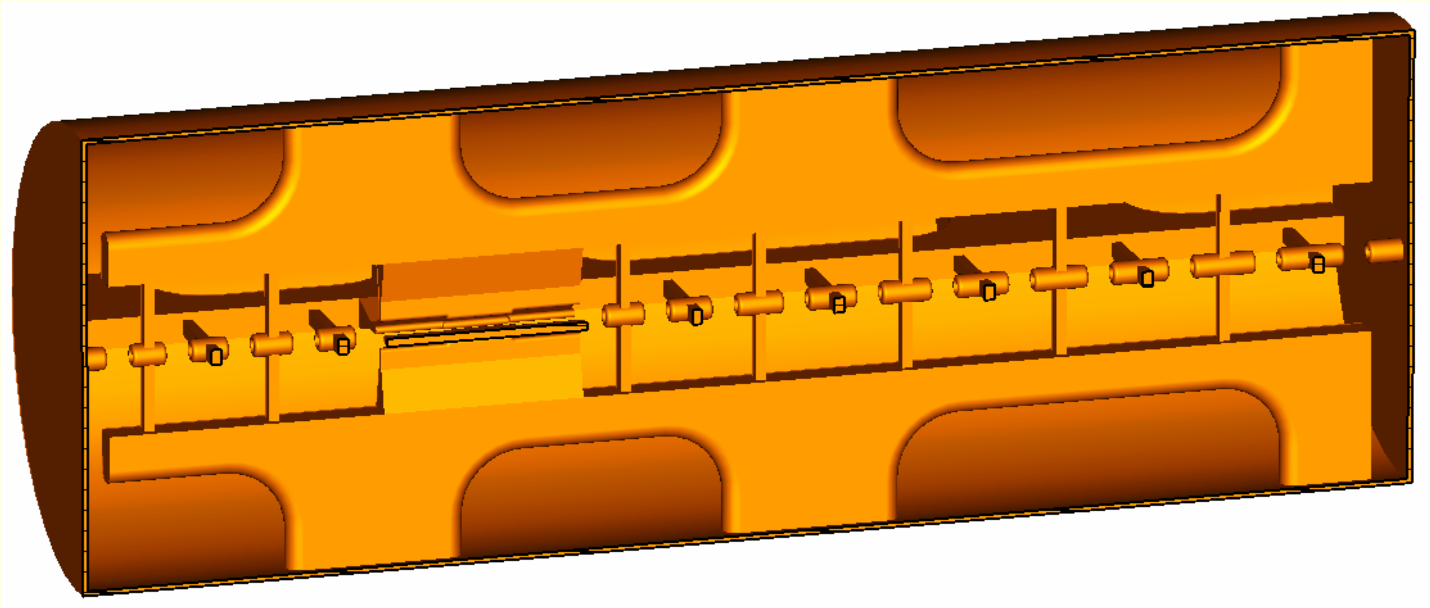
Hybrid Structure for ion injector I-4

Simplified scheme of I-4 accelerating structure



Frequency, MHz	81.5
Gap voltage, kV	600.
Aperture, mm	12.0
Cell number	14
Total length, mm	2650.
Output energy, MeV/u	4.9

Model of hybrid accelerating structure based on four vane cavity with coupling windows



Ion acceleration in I-4

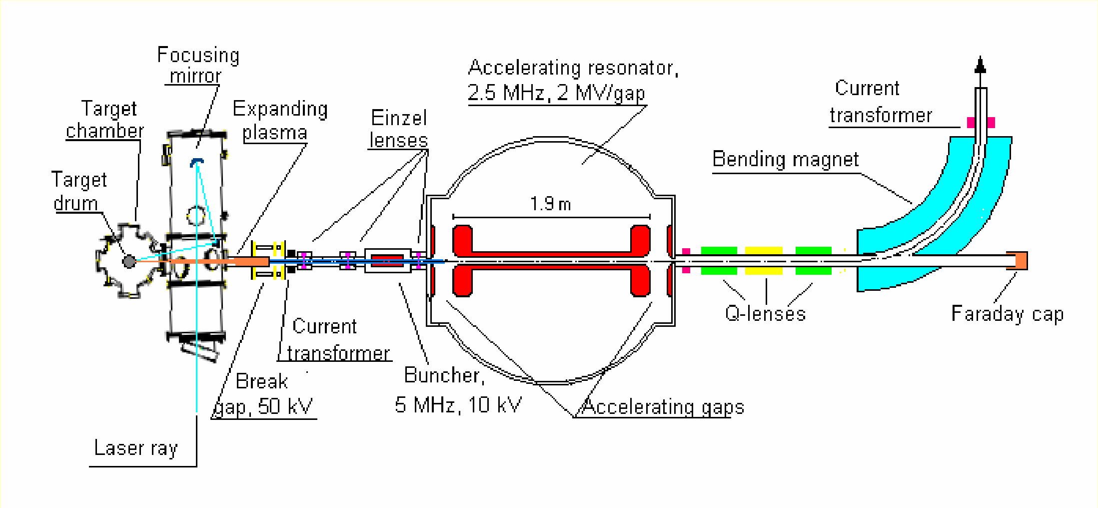
Beam parameters

F=81.4 MHz, A/Z$\leq$3, β_{inp}=0,0065, β_{out}=0,122, U=7 MV/u

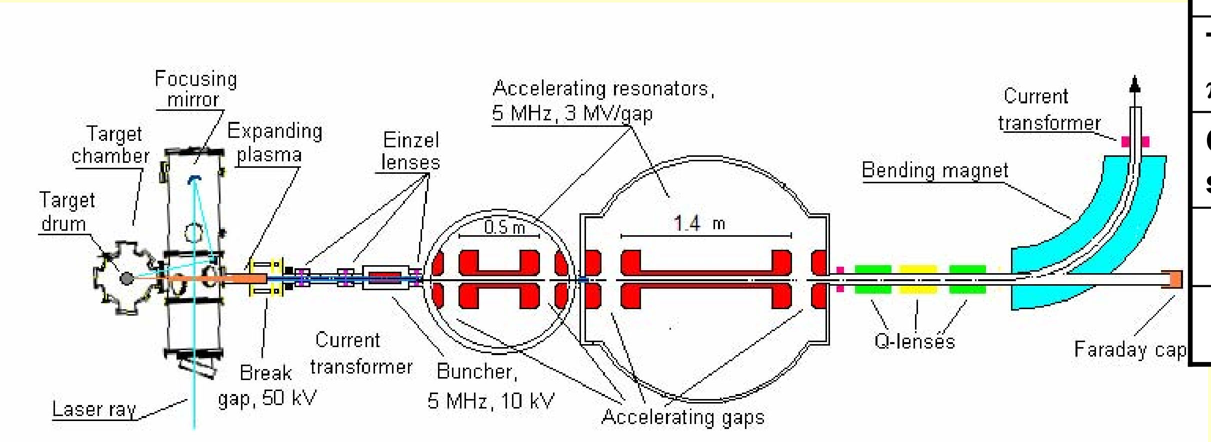
Ion	C^{4+}	Si^{10+}	Al^{11+}	Mg^{10+}	Si^{12+}	C^{6+}
U_{ion}, eV	68	415	471	396	552	475
A/Z	3	2.8	2.45	2.4	2.33	2
m/Z, MeV	2794	2608	2286	2236	2174	1863
p/Z, MeV/c	343	320	280	275	267	229

Upgrade of heavy ion injector I-3

Injector I-3 - A/Z=(2÷5), ~4MV



Injector I-3M - A/Z=(3÷10), ~12MV



Comparison parameters of I-3 and I-3M

Injector	I-3	I-3M
Accelerating frequency, MHz	2.504	~5.0
Number of resonators	1	2
Accelerating gaps	2	4
Accelerating voltage, MV	4	~12
Bunching voltage, kV	10	
Accelerating ions, A/Z	2-5	3-10
Injection energy, kV	50	
Trans. acceptance, $\pi \cdot$ mm mrad	~1000	
Output momentum spread, $\Delta p/p$, %	±1	
Transmission factor, %	~50	

Ion acceleration in I-3M

Accelerating structure

F=5 MHz, U=3x4 MV, d_U=0.25 m, l_1=0.5 m, l_2=1.4 m

A/Z	10(U^{24+})	9(U^{28+})	8(Au^{25+})	7(Ta^{26+})	6(Ag^{19+})	5(Ag^{22+})	4(Fe^{16+})	3(Ni^{18+})
U_{ion}, eV	600	836	763	789	512	974	506	624
m/Z, MeV	9315	8392	7452	6520	5589	4657	3726	2794
$\Delta\varphi$, rad	1.1	1.3	1.9	2.3	2.8	3.2	3.5	3.8
p, MeV/c	440	426	411	390	357	323	283	240
V, MV	10.4	10.8	11.3	11.6	11.4	11.2	10.7	10.3
E, MeV/u	1.0	1.2	1.4	1.6	1.9	2.2	2.6	3.4
β	0.046	0.051	0.055	0.059	0.064	0.069	0.075	0.085

Upgrade of UK Ring

1. **Vacuum system**:
   - *replacement of vacuum chamber by thin-wall one*
   - *replacement of IP-vacuum pumps by IP+TSP*
   - *improvement of vacuum chamber baking system*

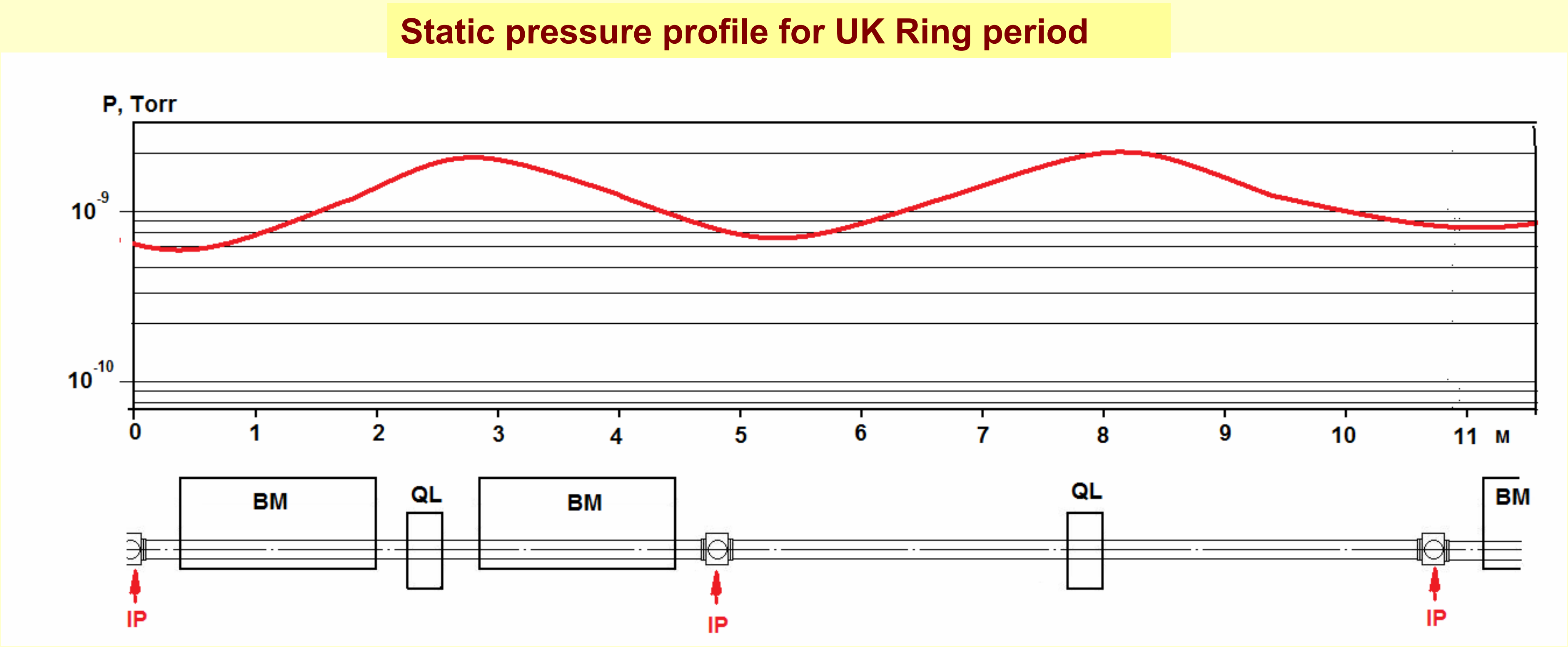
2. **Accelerating system**:
   - *installation of two additional accelerating stations to increase accelerating voltage up to 20 kV*

3. **New main power supply system**:
   - *high precision power supply of 10 kV/4 kA*

4. **New slow extraction systems**:
   - *to Target Hall (120) and Medical Building (101a)*

5. **New injection channel I-2/UK for proton beam**

UK Ring Vacuum system (2011)

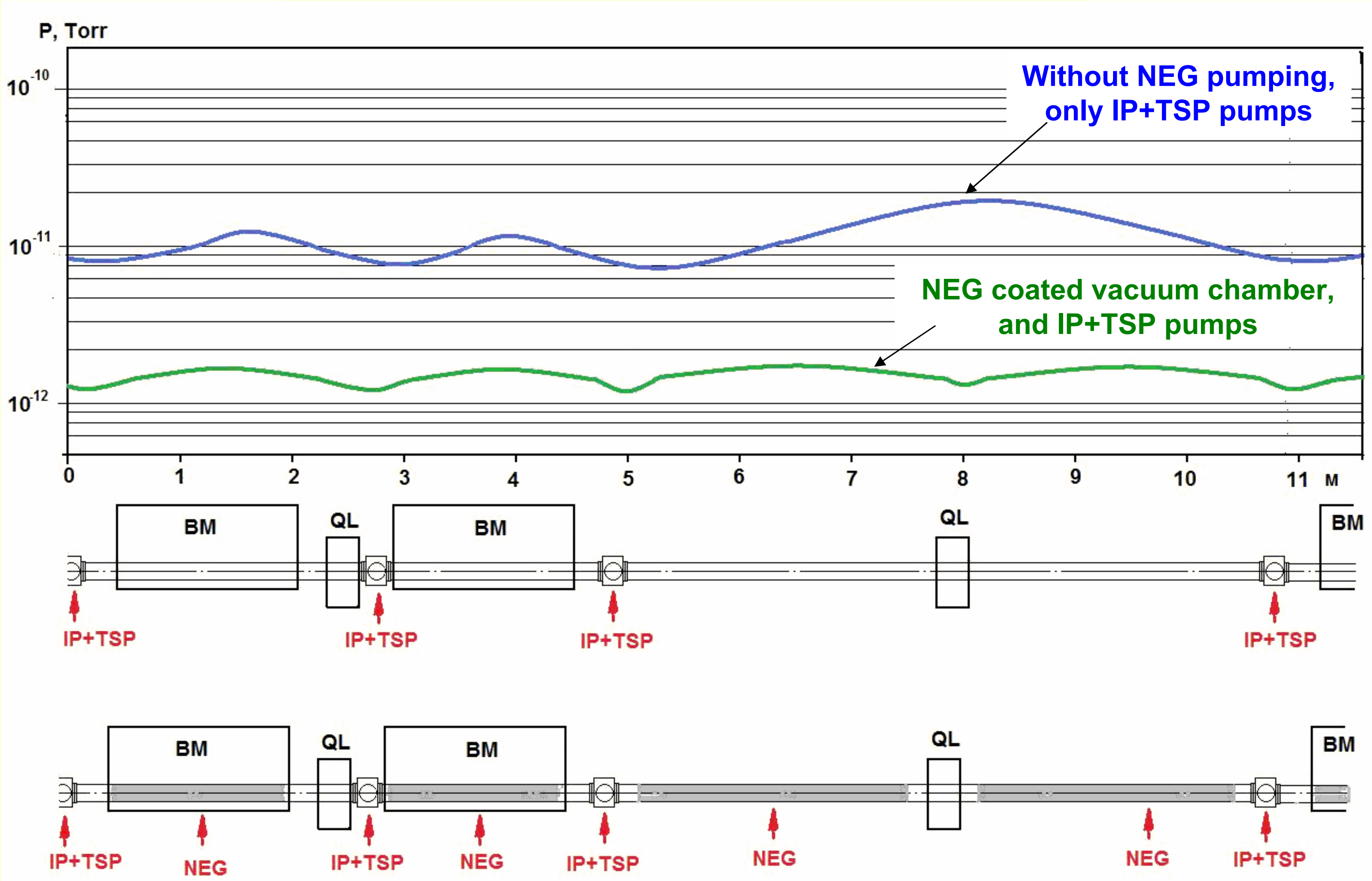


UK Ring period length

IP – Sputter ion pump

Upgrade of UK Ring Vacuum system

Static pressure profile for UK Ring period



IP – Sputter ion pump
TSP – Titanium sublimation pump
NEG – Non evaporable getter (Ti-Zr-V – coated vacuum chamber)

Upgrade of UK Ring Vacuum system

Comparison of UK and SiS18 Vacuum system

Parameter	**UK (2011)**	**SiS18**	**UK(project)**
η, $\frac{Torr\ l}{s\ cm^2}$	$\sim 2x10^{-12}$	$4x10^{-13}$	$<10^{-12}$
T_{bake}, C^o	150	200	200
S_{IP}, $\frac{l}{s\ m}$	7	6	9
S_{TSP}, $\frac{l}{s\ m}$	-	50	60
S_{NEG}, $\frac{l}{s\ cm^2}$	-	0.2	(0.2)
P, *Torr*	$\sim 10^{-9}$	$\sim 10^{-12}$	$\sim 10^{-11}(10^{-12})$

Upgrade of UK accelerating system

Upgrade of UK accelerating system is aimed increase of main magnet ramping rate by factor of 3÷4 to reduce the time of ion acceleration up to the maximal energy to ~150 ms.

Parameter	**UK (2011)**	**UK (project)**
Magnet ramping rate, T/s	1÷2	4÷6
Number of cavities	1x2	2x2
Accelerating frequency, MHz	0.7 ÷2.5 2.2 ÷10	
Cavity peak voltage, *MV*	10	20
Harmonic number	10÷15	

Ion acceleration in upgraded UK Ring

Accelerated beam parameters with injector I-4

$A/Z \leq 3$, $U_{inj} = 7$ MV/u, $\beta_{inj} = 0{,}122$, $F_{acc} = 0.7 \div 10$ MHz, $T_{UK} = 6.1\ \mu s$, $p_{max} = 4$ GeV/c

A/Z	3(C^{4+})	2.8(Si^{10+})	2.45(Al^{11+})	2.4(C^{5+})	2.33(Si^{12+})	2 (C^{6+})
E_{max}, MeV/u	668	744	910	941	981	1229
N_{max}	$8{,}1 \times 10^{11}$	$3{,}0 \times 10^{11}$	$2{,}4 \times 10^{11}$	$5{,}2 \times 10^{11}$	$2{,}1 \times 10^{11}$	$3{,}6 \times 10^{11}$

Accelerated beam parameters with injector I-3M

$A/Z \geq 3$, $U_{inj} = (1 \div 3.5)$ MV/u, $\beta_{inj} = (0.05 \div 0.09)$, $F_{acc} = 0.7 \div 10$ MHz, $T_{UK} = 9 \div 16\ \mu s$

A/Z	10(U^{24+})	9(U^{28+})	8(Au^{25+})	7(Ta^{26+})	6(Ag^{19+})	5(Ag^{22+})	4(Fe^{16+})	3(Ni^{18+})
E_{max}, MeV/u	78	95	120	154	204	283	417	668
$N_{max}(T_b = 5\ \mu s)$	2×10^{10}	1.7×10^{10}	2.4×10^{10}	2.8×10^{10}	3.5×10^{10}	2.4×10^{10}	4.3×10^{10}	5.1×10^{10}

Upgrade of U-10 Ring

1. **Improvement of vacuum up to <10^{-9} Torr:**

   - replacement of vacuum chamber for reduce of outgassing

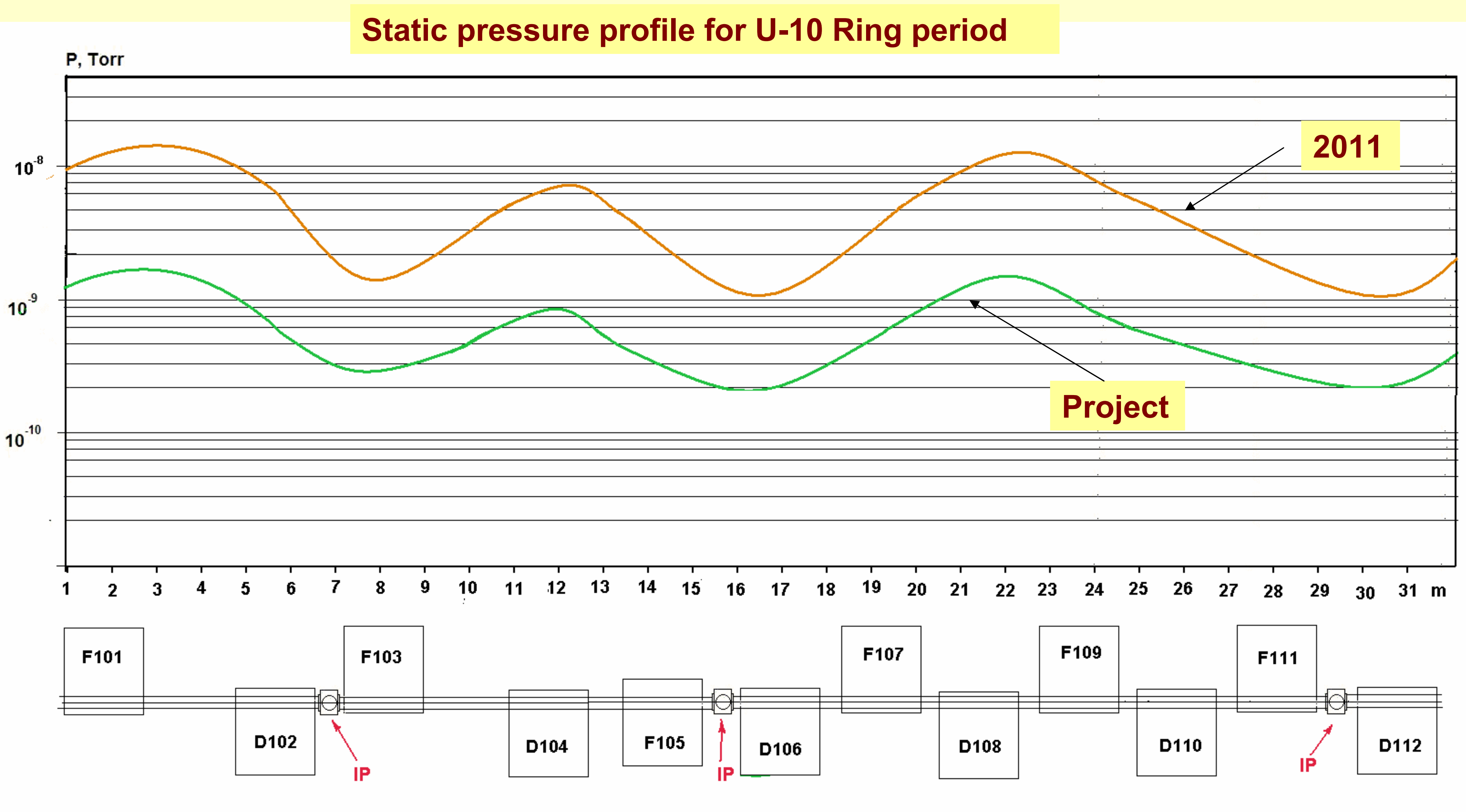
2. **Modification of charge exchange injection scheme:**

   - installation of magnet inflector for injection of any kind of ions from UK Ring
   - expanding of hor. acceptance for stacking beam up to A_x=100 π mm mrad
   - mastering of dynamic filling of accumulator Ring acceptance

3. **Construction of combined extraction system of 10Z MeV/c beam**

   - fast extracted beam for protonography of fast processes
   - slow extracted beam for nuclear research

Upgrade of U-10 Ring Vacuum system



IP – Sputter ion pump

Upgrade of U-10 Ring Vacuum system

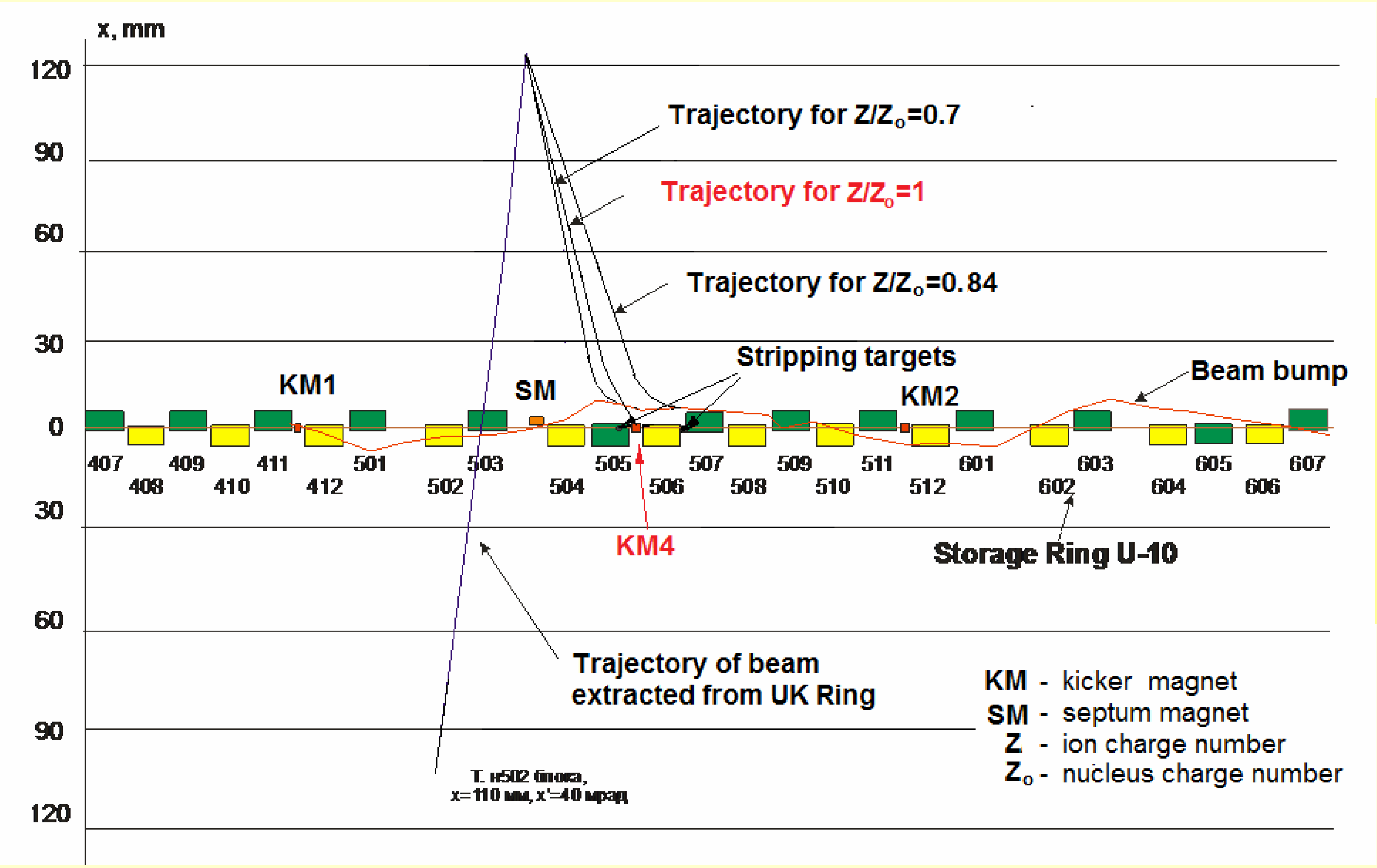
Comparison parameters of U-10 vacuum system

Parameter	**U-10 (2011)**	**U-10(project)**
η, $\frac{Torr\ l}{s\ cm^2}$	~10^{-11}	~10^{-12}
T_{bake}, C^o	-	200
S_{IP}, $\frac{l}{s\ m}$	4	4
P, *Torr*	~10^{-8}	~5×10^{-10}

Modification of charge exchange injection scheme

1. Installation of magnet inflector for injection of any kind of ions from UK Ring

2, Expanding of hor. acceptance for stacking beam up to A_x=100 π mm mrad

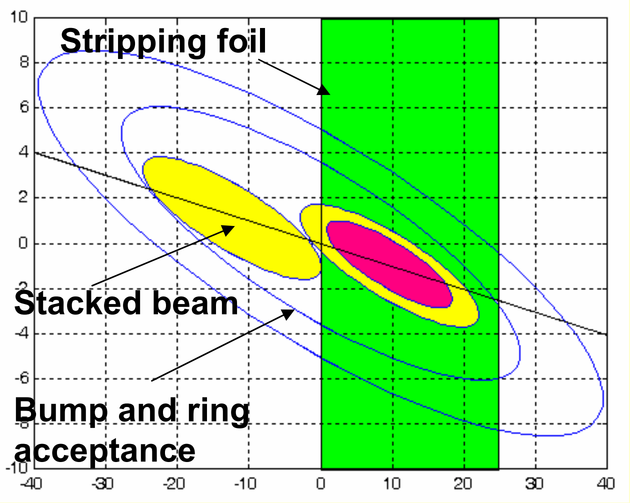


- injection channel will have to be modified for extension of dynamic range of stripping foil position on the orbit;
- aperture of vacuum chamber will have to be modulated in accordance with beam bump trajectory;
- stripping foil should be displaced in the process of beam stacking to the edge of hor. acceptance envelope;

3. Mastering of dynamic filling of accumulator Ring acceptance

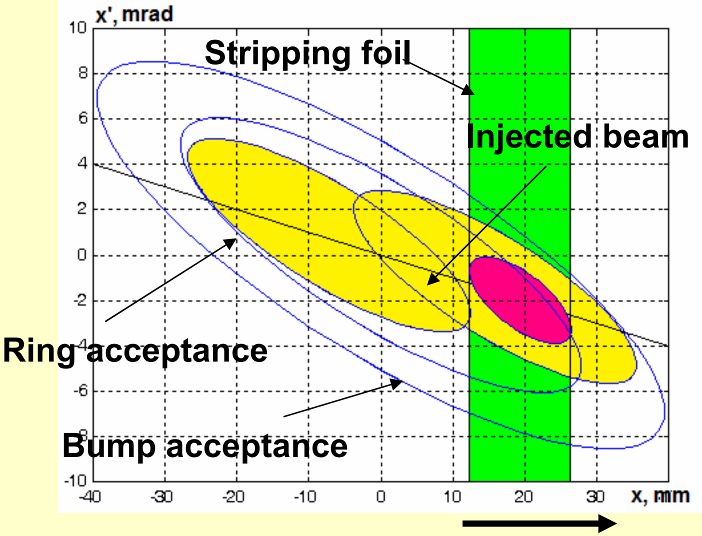
Dynamic filling of horizontal phase volume

Beam stacking into a_x=20 π mm mrad



ε_x=10 π mm mrad
a_x=20 π mm mrad
A_x=100 π mm mrad

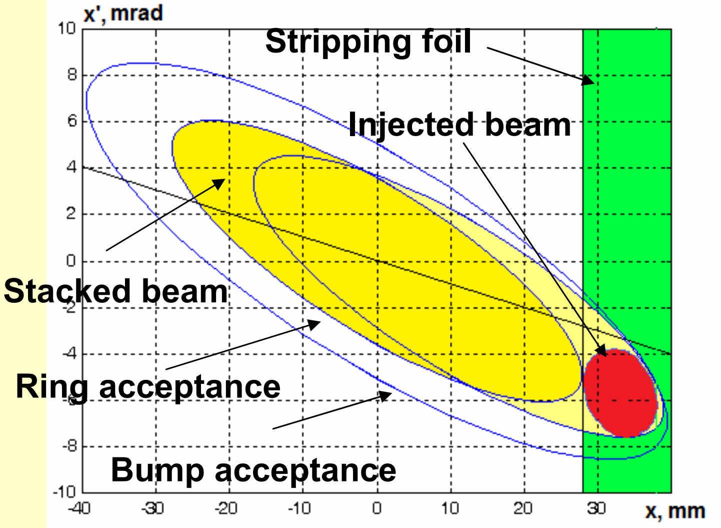
Beam stacking into a_x=50 π mm mrad



ε_x=10 π mm mrad
a_x=50 π mm mrad
A_x=200 π mm mrad

Stripping foil's displaced step by step to the edge of bump acceptance

Beam stacking into a_x=100 π mm mrad



ε_x=10 π mm mrad
a_x=100 π mm mrad
A_x=200 π mm mrad

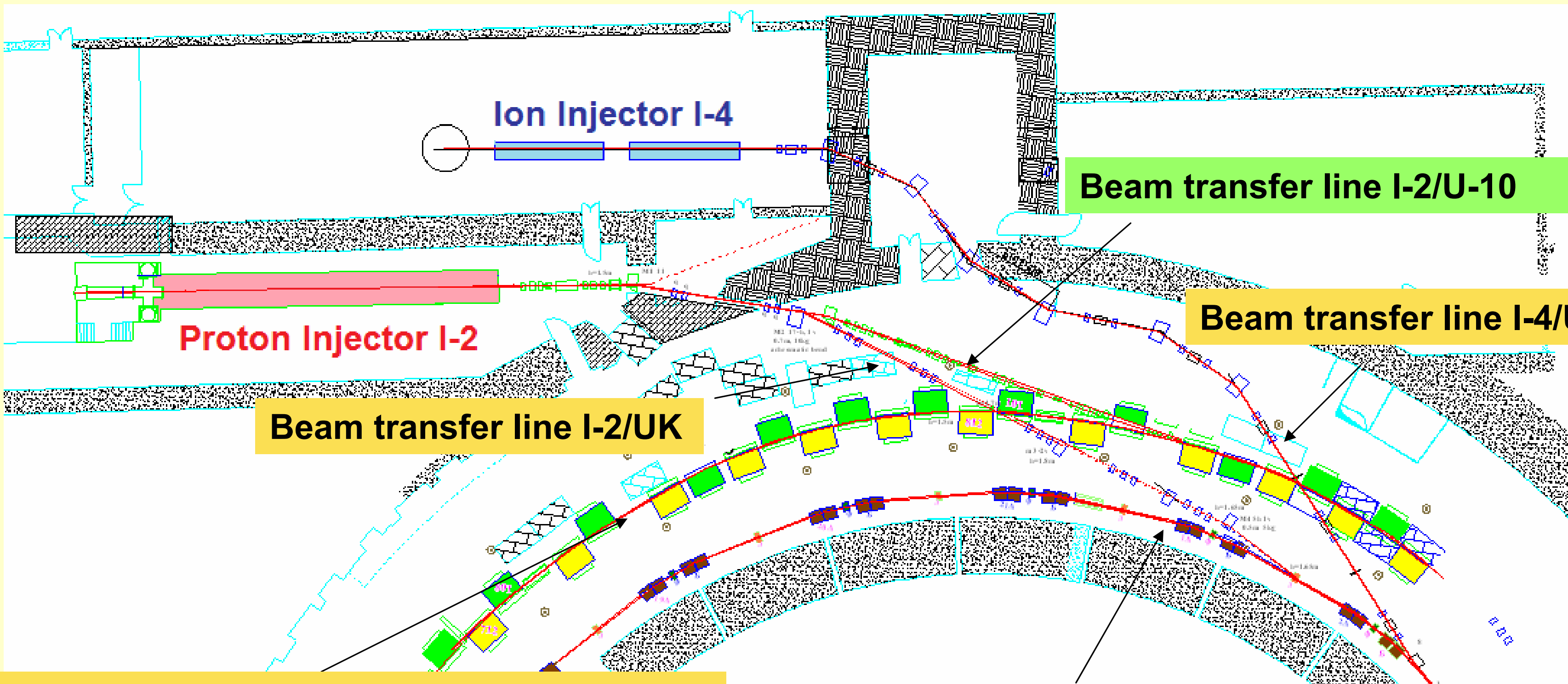
Development of ITEP-TWAC infrastructure

1. **Construction of Injection beam line from I-2 to UK Ring**

2. **Construction of slow extraction system for proton or ion beam from UK Ring to TH and MB**

3. **Construction of combined extraction system for proton or ion beam from U-10 Ring to BEX**

Project of expanded Injection Complex for ITEP-TWAC (2010)



Ring U-10:

Acceleration of proton and any ion beams up to the energy of 2.5-9 GeV for protons and 100 MeV/u – 4 GeV/u for ions,

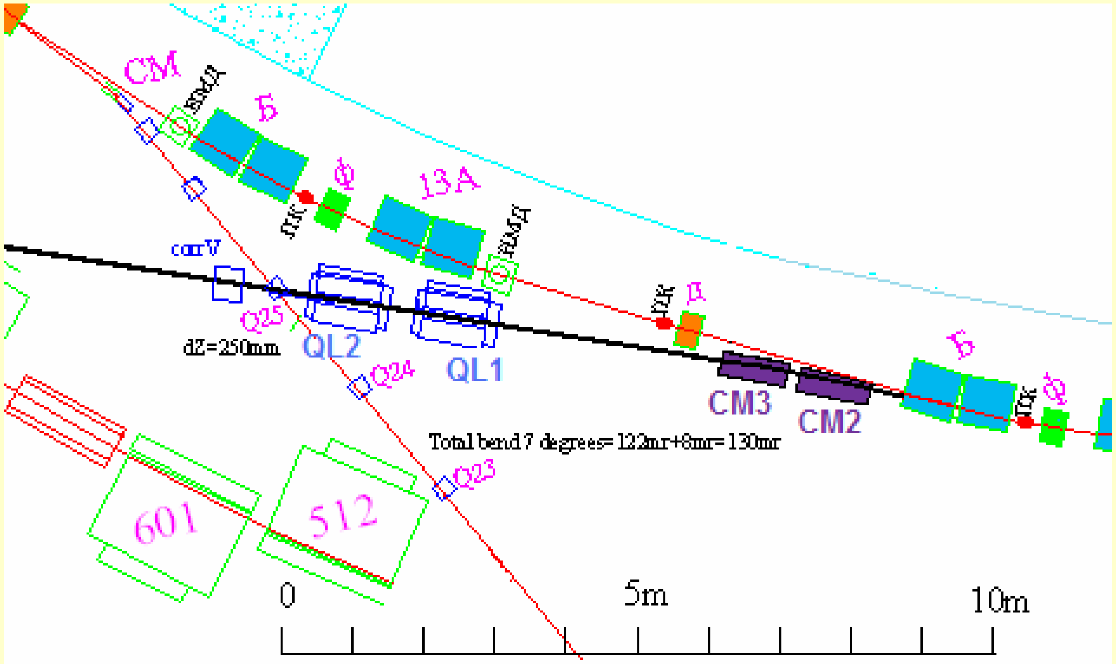
Stacking of nuclei at the energy of 200-700 MeV/u

Ring UK:

Acceleration of proton and any ion beams up to the energy of 50 MeV – 2.5 GeV for protons and 10 MeV/u – 700 MeV/u for ions

Project of slow extraction system for UK Ring (2010)

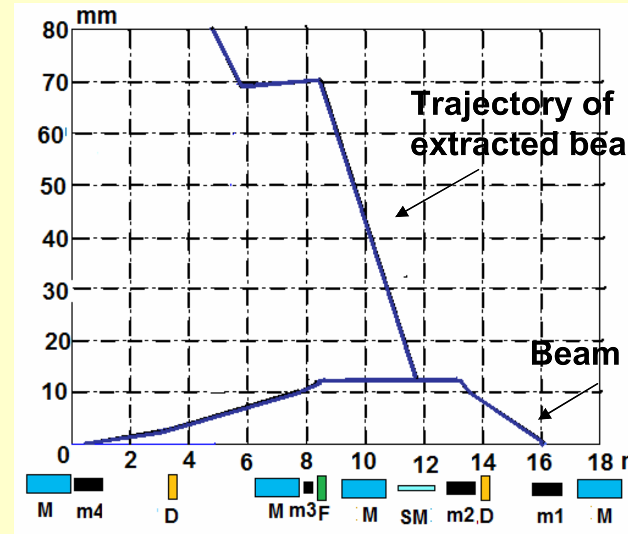
Extracted beam transfer line



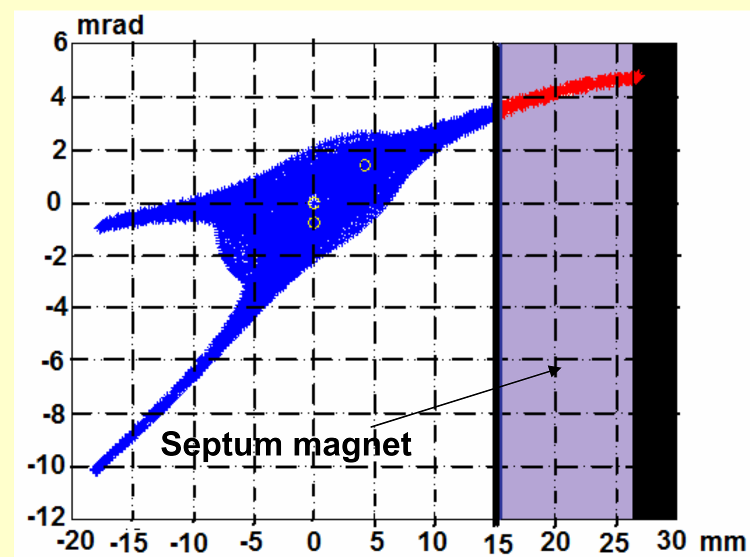
System parameters

Number of extraction directions	- 2
Proton energy	- from 40 MeV up to 2,2 GeV
Ion energy	- from 10 MeV/u up to 1 GeV/u
Length of spill	- 100-500 ms
Efficiency	- up to 80%

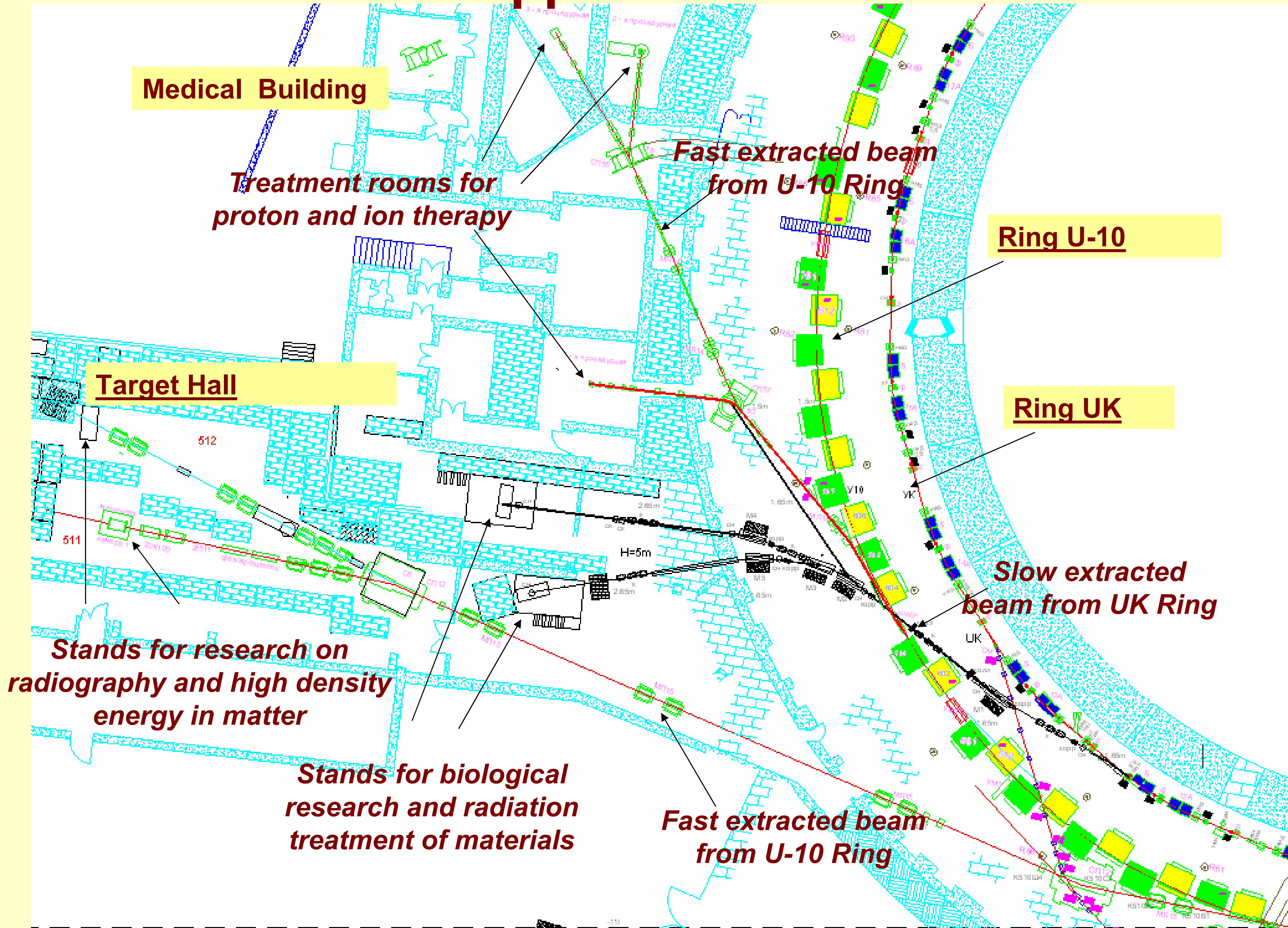
Beam kinematics at extraction



Phase space portrait of extracting beam

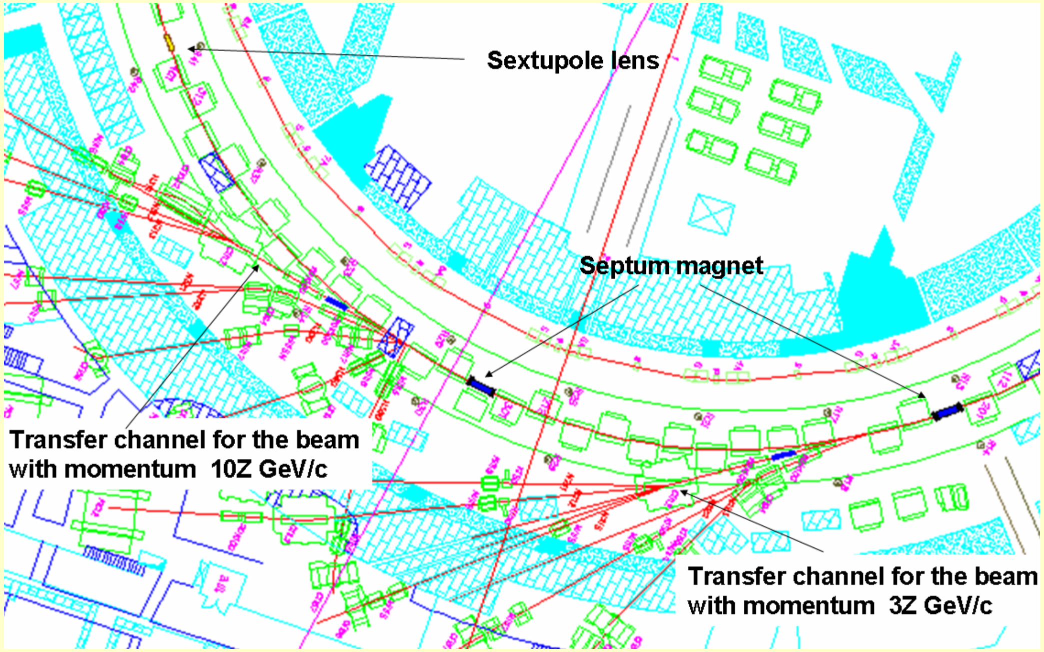


Layout of expanded experimental area for applied research

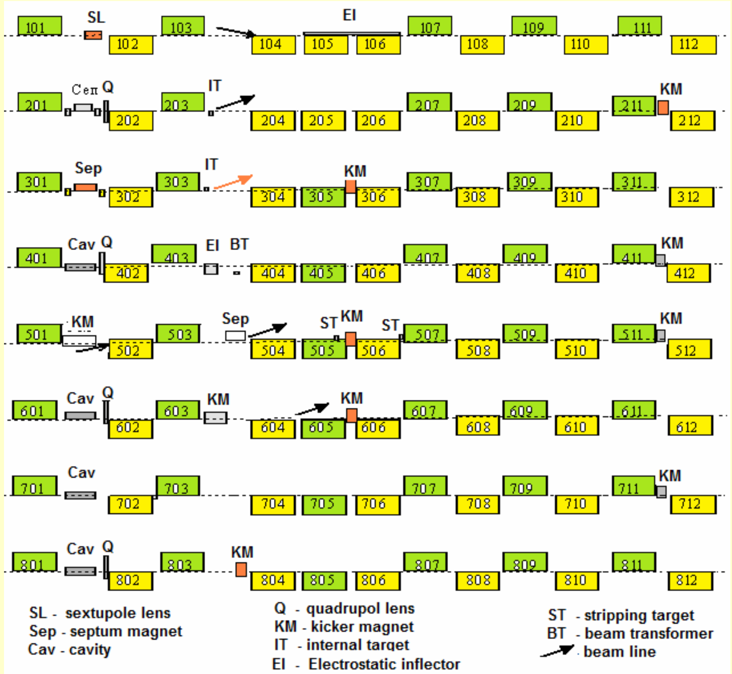


Combined extraction of beam with momentum of 10Z GeV/c from U-10 Ring to BEH (2011)

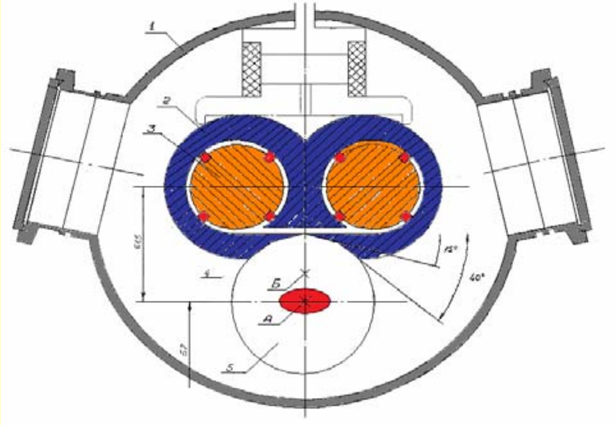
Scheme of beamlines from U-10 to BEH



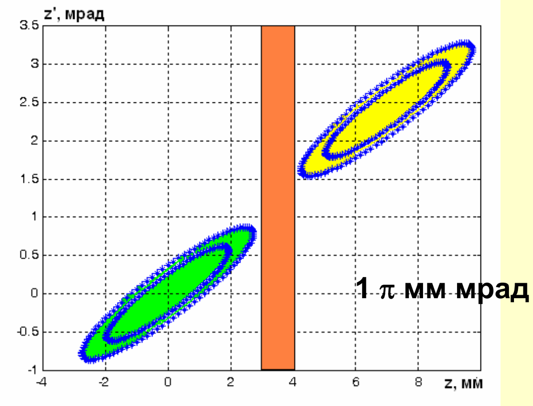
Scheme of equipment location in U-10 lattice



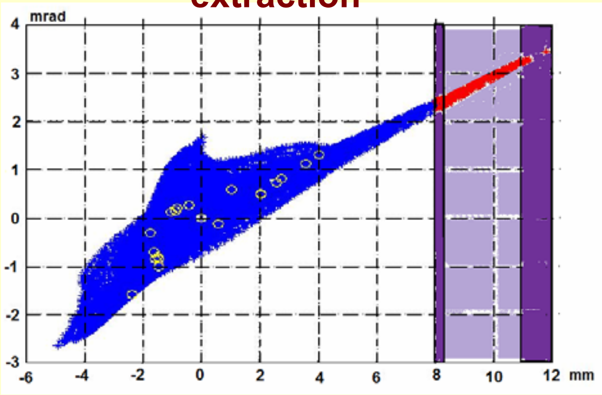
Septum magnet of Lambertson type



Vertical emittance at fast extraction



Vertical emittace at slow extraction



Upgraded ITEP-TWAC Operation Parameters

Mode of operation	Accelerators	Beam energy, MeV/u	Regime of beam extraction
Proton acceleration	*I-2* *I-2/U-10* *I-2/UK*	25 up to 230 up to 3000 up to 9300 up to 3000 up to 9300 up to 3200	pulse, 10 μ/s , 10^{13} medical extraction, 200 ns, $5x10^{10}$ fast extraction, 800 ns, 10^{11} internal target, 1s , 10^{11} slow extraction to 210-212 tracts , 1s, 10^{11} combined extraction to 310-312 tracts, slow extraction to TH and MB, 1s, 10^{12}
Ion acceleration, *C, Al, Si, Fe, Cu, Ag* *Ta, W. Au, Pb, U*	*I-3/UK* *I-3/UK/U-10*	1,5 – 400-700 up to 4000	fast extraction, 800 ns, *C(400 MeV/u, $2x10^9$), Al (230 MeV/u, $5x10^8$), Fe (230 MeV/u, $2.5x10^8$), Ag (100 MeV/u, $2x10^7$),* slow extraction to TH and MB, 1s, 700 MeV/u *C(10^{11}), Al ($5x10^{10}$), Si ($5x10^{10}$),Ni(670 MeV/u,$2x10^{10}$), Ag(280 MeV/u, ~10^{10}), Au(120 MeV/u,~10^{10}), U(90 MeV/u, ~10^{10})* internal target, 1s, fast (800 ns, 3 GeV/c) and slow extraction, (1 s, 3 GeV/c) *C(4 GeV/u, $5x10^8$), Al (4 GeV/u, $1x10^8$), Fe (3.6 GeV/u, $2x10^7$),* combined extraction to 310-312 tracts,
Nuclei accumulation, *C, Al,Fe, Si* *Ti, Ni, …*	*I-3/UK/U-10*	200-300-700	fast extraction with compression to 150 ns, continue extraction of stacking beam *C(~10^{13}),Al ($5x10^{12}$), Si ($5x10^{12}$), Ni(670 MeV/u,$2x10^{12}$)*

X – in operation 2011, X – after upgrading

Operation upgraded ITEP-TWAC for users

Research fields with proton and ion beams	Beams	Beam time, hours		
		2010	2011	2014 (2016)
Adron physics and relativistic nuclear physics	p (2-9.3 GeV, $10^{11}s^{-1}$) C (4 GeV/u, $10^{8}s^{-1}$) Al, Ti, Si, Fe, Ni	850	702	4500
Methodical research	p (1-9.3 GeV, $10^{11}s^{-1}$) C, Fe(0,2-4 GeV/u, $10^{8}s^{-1}$)	2045	2450	2000
Physics of high density energy in matter	C, Al, Si, Fe, Ni (300 MeV/u, $4x10^{10}s^{-1}$)	330	288	500
Radiobiology and medical physics	p (250 MeV, $10^{11}s^{-1}$) C (200-400 MeV/u, 10^{9} s^{-1})	2040	2320	4500
Proton therapy	p (250 MeV, $10^{11}s^{-1}$)			
Radiation treatment of materials	p (20-800 MeV, $10^{11}s^{-1}$) Fe, Ag (40-200 MeV/u, 10^{8} s^{-1}) Ta, Au, Pb, U	550	779	2000
Total		5815	6539	13500

The doubling beam time for research

Conclusion

1) Conception of ITEP-TWAC renewal and upgrading is based on demanding of fundamental, applied and technological research with proton and ion beams in the wide range of intermediate energies for nuclear science, industry, biology, medicine and education on the subject of nuclear technologies.

2) The progress in technology of Laser Ion Source with 100J CO_2 laser gives possibility of high charge state ion beam generation with $Z/A \geq 0.4$ for ions up to A~60 and with $Z/A \geq 0.1$ for ions up to A~200.

3) Upgrading of the heavy ion injector I-3 and commissioning of new light ion injector I-4 will be the base for cardinal increasing of intensity for accelerated in UK Ring ion beams in wide range of mass number values.

4) Acceleration of heavy ions with mass number up to A~200 in synchrotron UK will be achieved first of all as a result of ring vacuum system upgrade for the vacuum less than 1×10^{-11} Torr on the base of modern vacuum technology implementing.

5) Upgrading of U-10 Ring Accelerator systems will allow to increase significantly the intensity of accelerated proton and any kind of ion beams and to promote the multiple charge exchange injection technology for getting of super high density heavy ion beams.

6) Development of ITEP-TWAC facility Infrastructure is aimed mastering of multimode machine operation making generation proton and ion beams of both U-10 and UK synchrotrons in parallel.

7) Implementation of proposed conception renewal will allow to return into operation the ITEP-TWAC Facility on a new qualitative level of the operational parameters