Status of The Basic Facilities & Accelerator Activities at JINR

I.N. Meshkov

1. In memory of Academician V.I. Veksler - the Workshop at JINR
4-6 March 2002

2. Basic Facilities in operation
2.1. Nuclotron run
2.2. IBR-2 operation & refurbishment
2.3. Cyclotrons
2.4. Phasotron operation

3. Projects under development
3.1. DRIBS
3.2. IREN
3.3. LEPTA
3.4. DELSY

4. Activity in collaboration
4.1. LHC project (CERN)
4.2. CLIC project (CERN)
4.3. Physics of charged particle beams
4.4 Ion sources development
4.5. TESLA Test Facility & X-ray FEL

In memory of V. I. Veksler
(1907 - 1966)

International Seminar "Accelerators of Particles and Nuclei: Past, Present and Future." (ISAPAN-02)

4-6 March 2002, Dubna, Russia

Main Seminar Topics

- accelerator construction and development
- detectors development
- main discoveries of the last century
- developments in the theory of particle interactions

Seminar Organizers

- Joint Institute for Nuclear Research (JINR)
- Lebedev Physics Institute of the Russian Academy of Sciences
- Division of Nuclear Physics of the Russian Academy of Sciences
- Ministry of the Russian Federation for Atomic Energy
- Ministry of Industry, Science and Technologies of the Russian Federation

Sponsored by

- International Scientific Technical Center
- Russian Foundation for Basic Research

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The information about the seminar, JINR and Dubna is available on the web sites: http://www.jinr.ru or http://www.lhe.jinr.ru

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Russian

BASIC FACILITIES OF JINR

English

operation time table

January	Febr	March	April	May	June	July	August	Septem	Oct	Nov	Decemb	2002
January	Febr	March	April	May	June	July	August	Septem	Oct	Nov	Decemb	2001

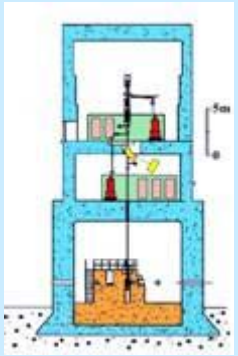
NUCLOTRON

IBR-2

U 400

Phazotron

U 400 M

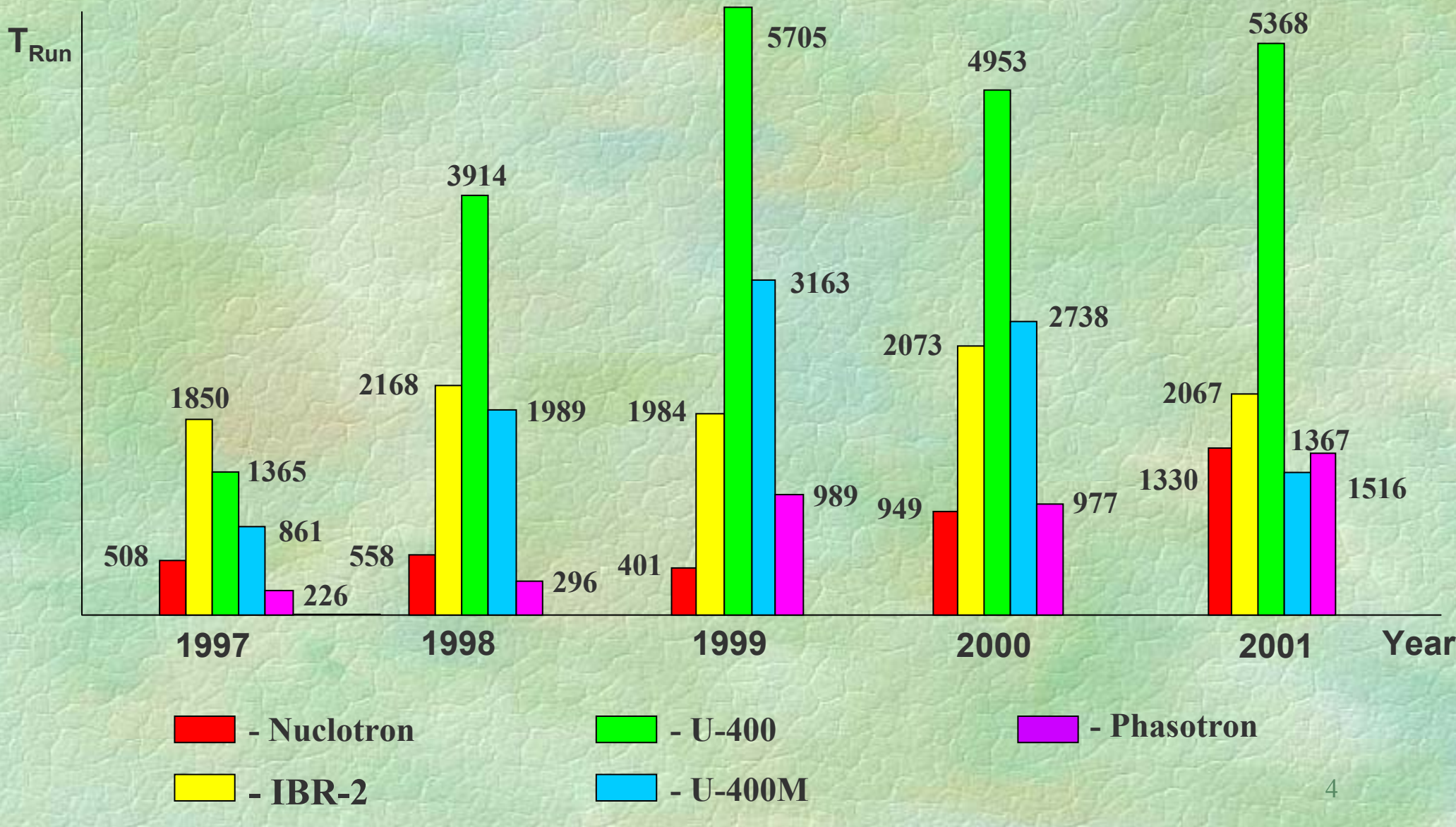


IREN

- facility is in operation

Basic Facilities Operation

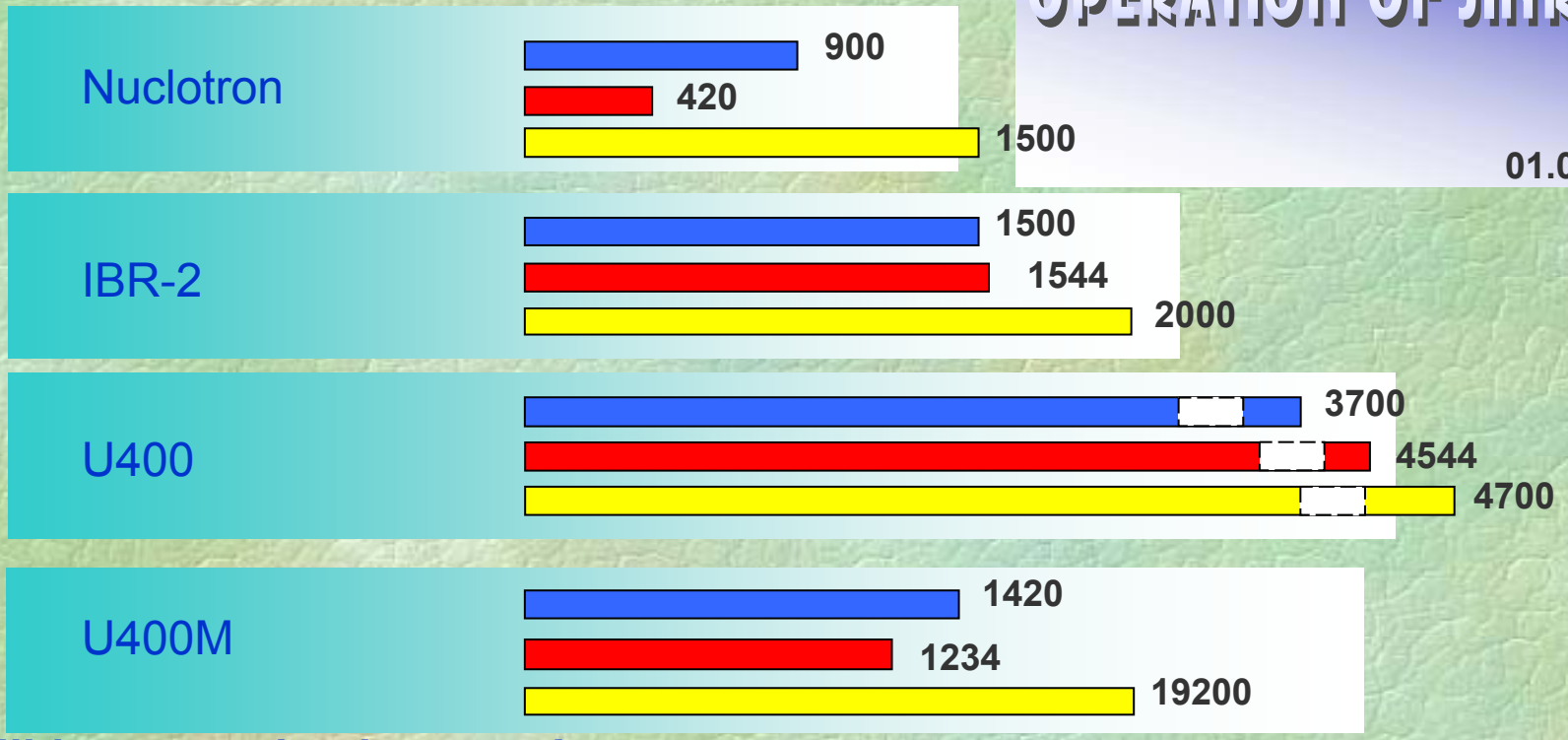
1997 – 2001



OPERATION OF JINR FACILITIES in 2001

01.01÷ 31.10.2001

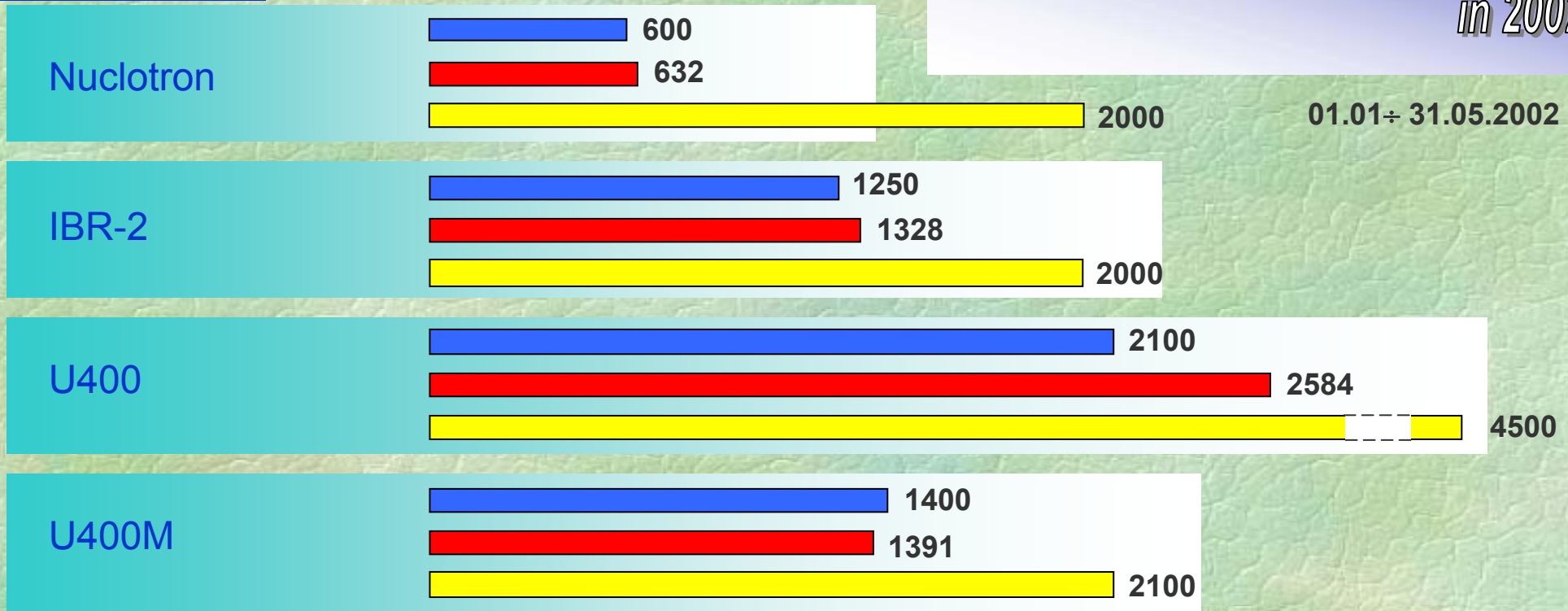
Basic Facilities



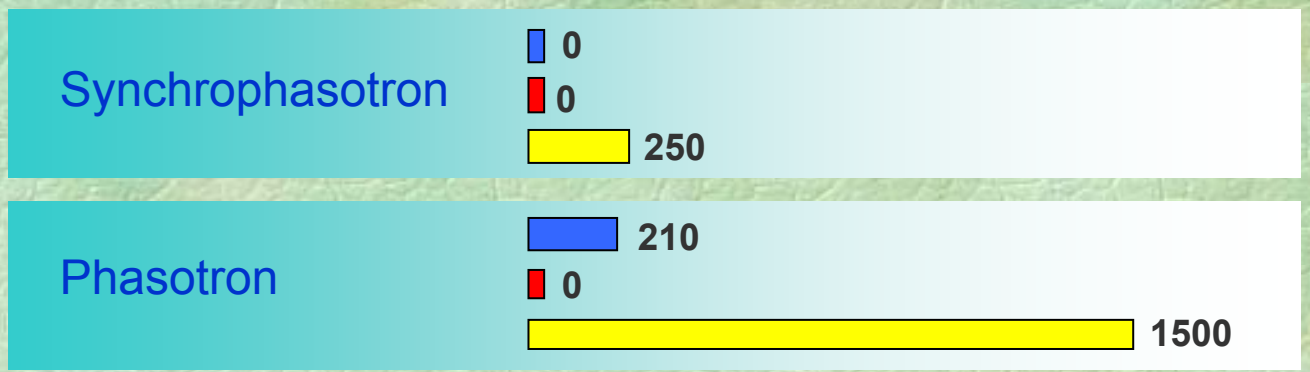
Facilities operating by users' request

OPERATION OF JINR FACILITIES in 2002

Basic Facilities



Facilities operating by users' request



- planned
- actual
- planned for year 2002

Nuclotron

Break-through at the Nuclotron 2001-2002

OPERATION:
Runs ## 19, 20, 21 (2001) => 1330 h
Run #22 (March 2002) => 632 h

Main result: Beginning of effective work for experiments:

- **Run duration enhancement : 450 ==> 865 hours**
- **Extracted beams for experiments :**

p	d	^{4}He	^{7}Li	^{10}B	^{12}C	^{24}Mg	^{84}Kr
$3\cdot10^{10}$	$2\cdot10^{10}$	$8\cdot10^{8}$	$1\cdot10^{9}$	$2\cdot10^{7}$	$1\cdot10^{9}$	$2\cdot10^{7}$	$1\cdot10^{3}$

- **Extracted ion energy ≅ 5.3 ·(Z/A) GeV/u**

  project =>12 ·(Z/A) GeV/u

- **Extraction efficiency => 95%**
- **Extracted beam quality and flat top duration increase**
- **Diagnostics development:**

  Betatron tunes => measured at injection and at the flat tops

- **Magnetic system development:**

  B_{max} : achieved => 1.5 T

  with the beam => 1.2 T

  project => 2 T

- **Technological maintenance improvement:**

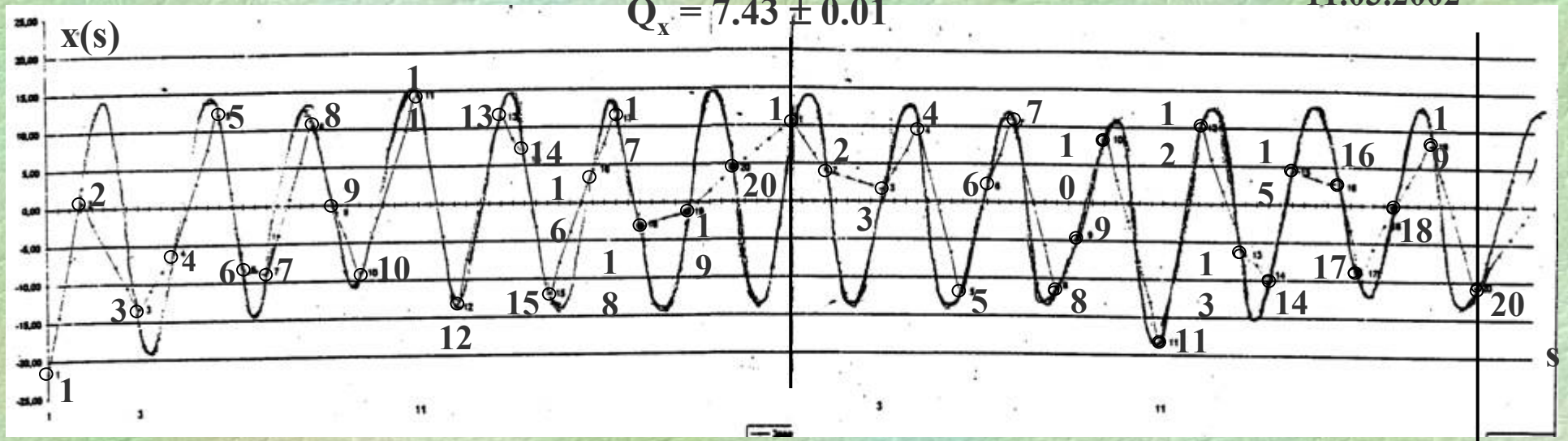
  Power and material consumption:
  Electricity <P> = 2.4 MW
  Liquid nitrogen8.33 tons/day
  Gaseous helium76 normal m^3 / day

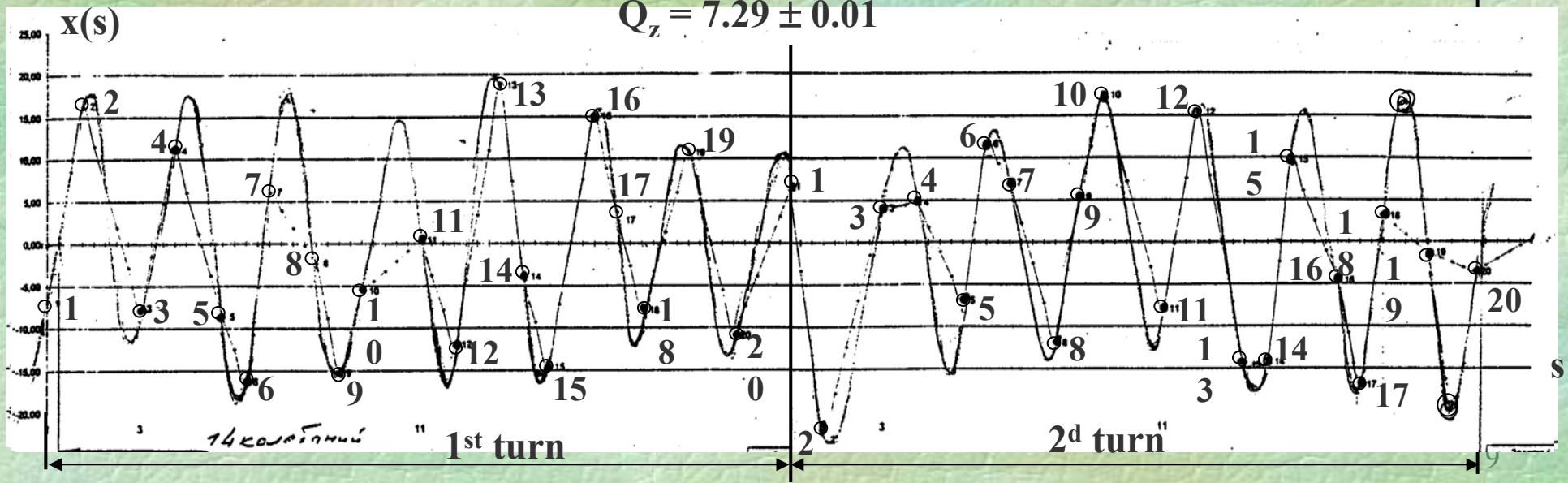
Psychological effect => the team efficiency enhancement !

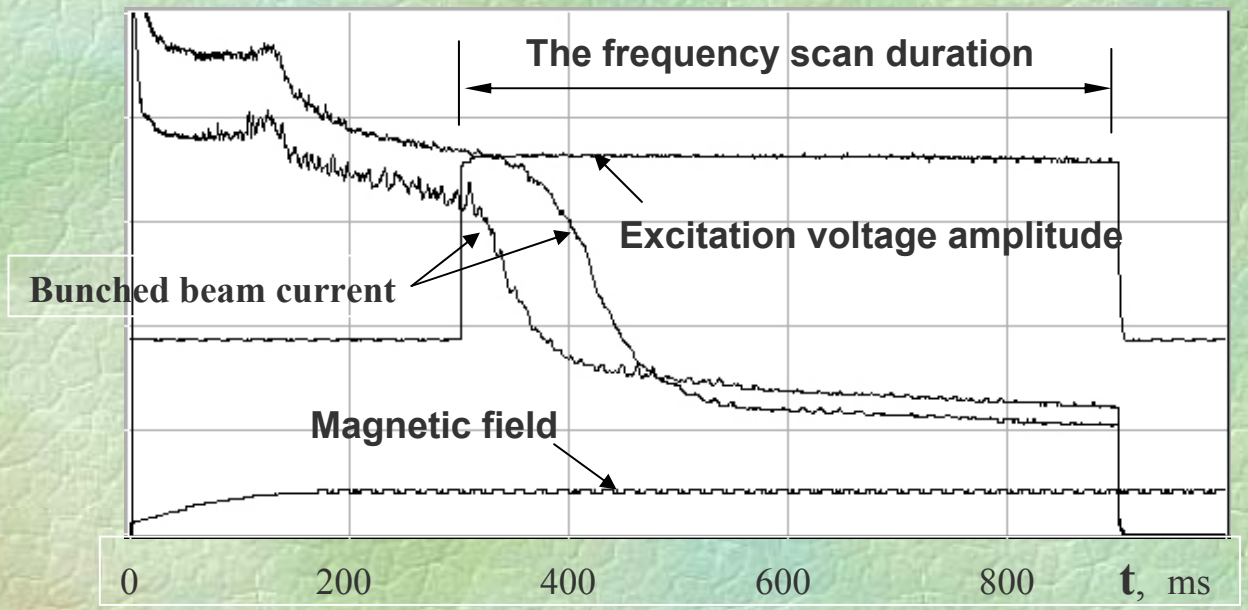
Coherent betatron oscillation at injection

1,2,3,…,20 – pick up station numbers

11.03.2002







Beam Transfer Function Method

The beam intensity loss at the excitation of betatron oscillations (two different settings of quads current)

Nuclotron Machine Development

Betatron tune measurements

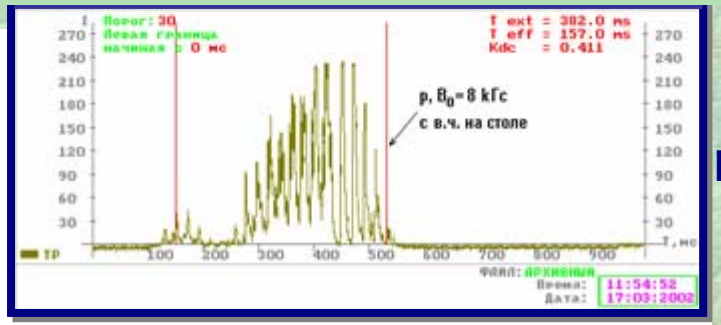
Method	B [kG]	Q_x	Q_z
Working point			
"First turns"	0.29[1)]	7.43 ±0.01	7.29 ±0.01
Resonance excitment	2.0	n.2 – n.4[2)] ±0.01	n.2 – n.4[2)] ±0.01
Fourier analysis	0.29[1)]	n.35±0.01[3)]	n.35±0.01[3)]
Project point[4)]			
"First turns"	0.29[1)]	6.85 ±0.01	6.51 ±0.01
Fourier analysis	0.29[1)]	n.82±0.01[3)]	n.75±0.01[3)]

[1)] at injection
[2)] at different quads gradient, fractional part measured
[3)] fractional part measured
[4)] no acceleration is obtained yet because> closed orbit correction is needed (the lack of time!)

Veksler-Baldin Laboratory of High Energies

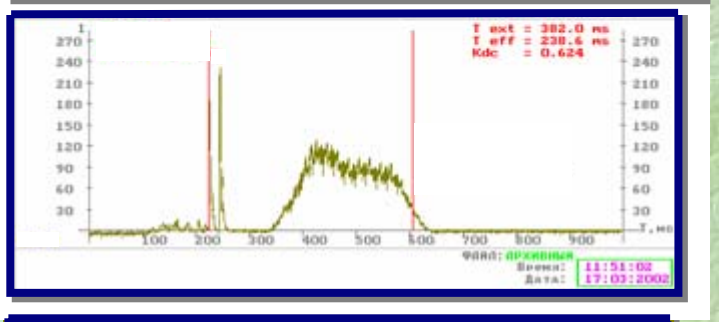
NUCLOTRON RUN # 22

(26.02 – 24.03.2002)



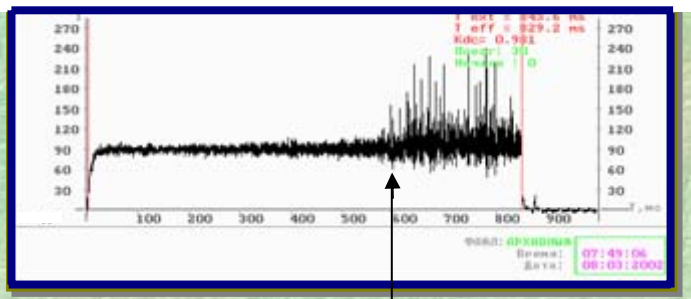
RF is ON

No feed back



RF is OFF

No feed back



RF is OFF

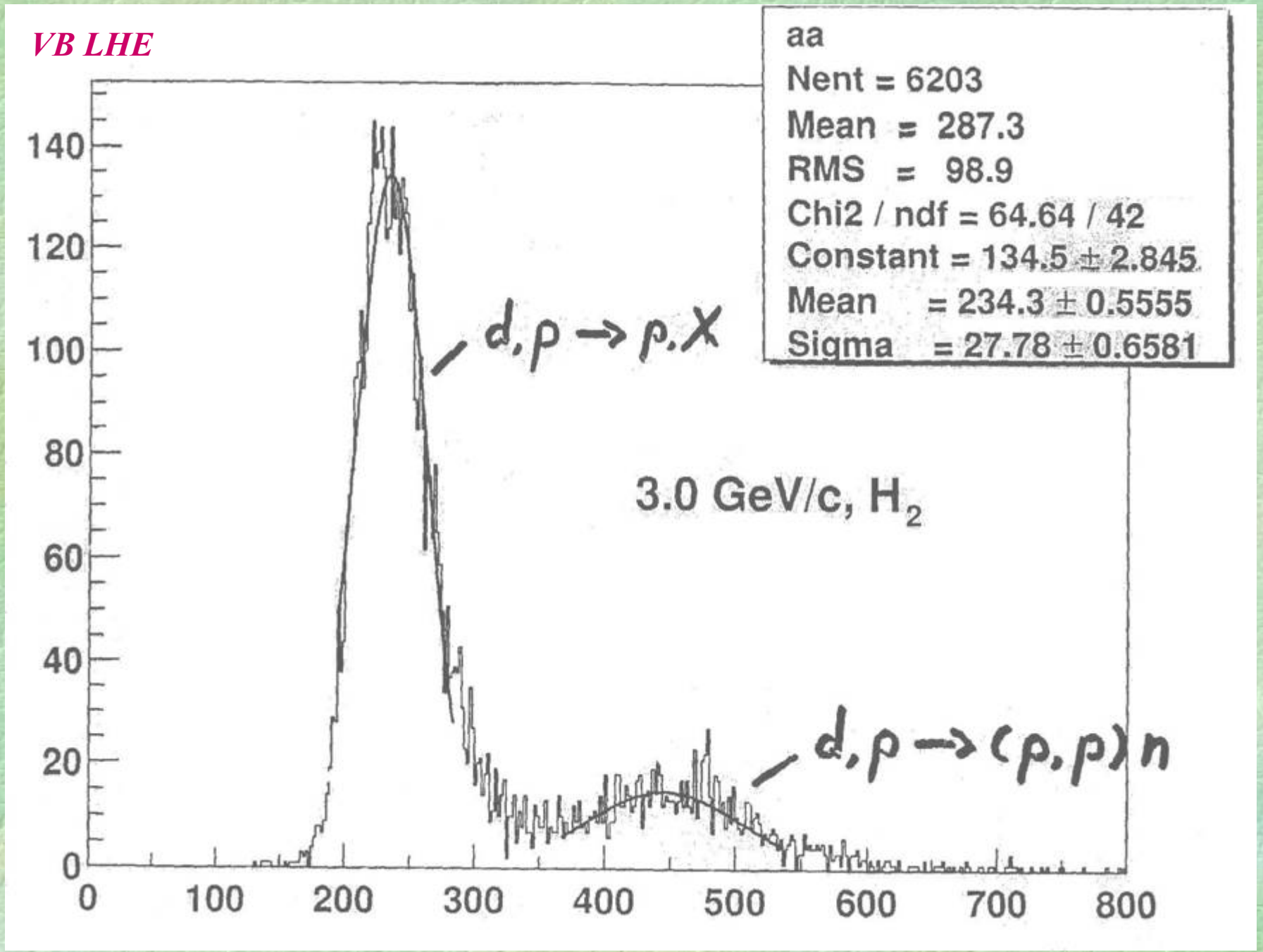
Feed back is ON

feed back "saturation"

The extracted beam intensity vs. time:

The signal from ionization chamberin the transfer channel, one can see the effect of the feedback "beam intensity – extraction quads" B = 8 kG

VB LHE


aa
Nent = 6203
Mean = 287.3
RMS = 98.9
Chi2 / ndf = 64.64 / 42
Constant = 134.5 ± 2.845
Mean = 234.3 ± 0.5555
Sigma = 27.78 ± 0.6581
d,p → p,X
3.0 GeV/c, H2
d,p → (p,p)n
0
20
40
60
80
100
120
140
0
100
200
300
400
500
600
700
800

NUCLOTRON :

Main Goals in 2002

1. **Delivery of polarised deuteron beam available for users :**
   generation (ion source !)
   injection,
   acceleration and extraction

   December 2002
   Run # 24

   Status:
   - **d^- source => ~ $3 \cdot 10^{13}$ nonpolarised deuterons per pulse**
   - **conceptual design of injection scheme is developed**

2. **Beam diagnostics development**

3. **Machine study and parameter improvement: betatron tunes, acceptance, beam losses decrease, etc.**

   June - July 2002
   Run # 23

4. **Particle energy enhancement (if required funding is available!)**

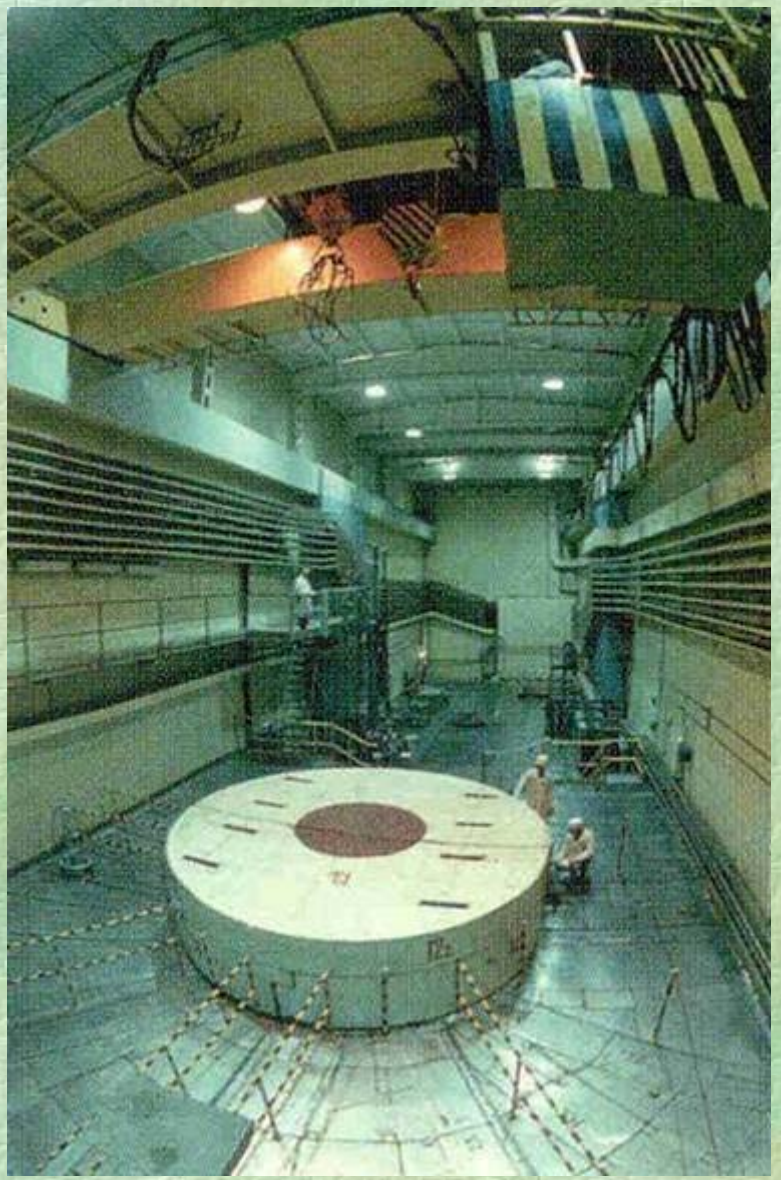
Nuclotron Beams

	Intensity (particles per cycle)		
Beam	2001	2003 development I	2007 development II
p	$3 \cdot 10^{10}$	$1 \cdot 10^{11}$	$1 \cdot 10^{13}$
d	$2.3 \cdot 10^{10}$	$5 \cdot 10^{10}$	$1 \cdot 10^{13}$
^{4}He	$8 \cdot 10^{8}$	$5 \cdot 10^{9}$	$2 \cdot 10^{12}$
^{7}Li	$1 \cdot 10^{9}$	$2 \cdot 10^{10}$	$5 \cdot 10^{12}$
^{10}B	$2.3 \cdot 10^{7}$		
^{12}C	$1 \cdot 10^{9}$	$7 \cdot 10^{9}$	$2 \cdot 10^{12}$
^{20}Ne		$1 \cdot 10^{8}$	$5 \cdot 10^{9}$
^{24}Mg	$2.0 \cdot 10^{7}$	$3 \cdot 10^{8}$	$5 \cdot 10^{11}$
^{40}Ar		$3 \cdot 10^{7}$	$2 \cdot 10^{9}$
^{56}Fe		$1 \cdot 10^{8}$	$1 \cdot 10^{9}$
^{84}Kr	$1 \cdot 10^{3}$	$2 \cdot 10^{7}$	$5 \cdot 10^{8}$
^{131}Xe		$1 \cdot 10^{7}$	$2 \cdot 10^{8}$
^{209}Bi		$3 \cdot 10^{6}$	$1 \cdot 10^{8}$
^{238}U			$1 \cdot 10^{8}$
$d\uparrow$		$3 \cdot 10^{9}$	10^{10}

Development I – upgrade of existing ion sources
Development II – booster + new ion sources

IBR-2: Operations & refurbishment

Frank Laboratory for Neutron Physics



IBR-2 OPERATION IN 2002

Five runs:
#1 265 h
#2 - 264 h
#3 - 263 h
#4 - 262 h
#5 - 274 h
in accordance with the schedule

Presently – summer routine repair of reactor (according the operation schedule).

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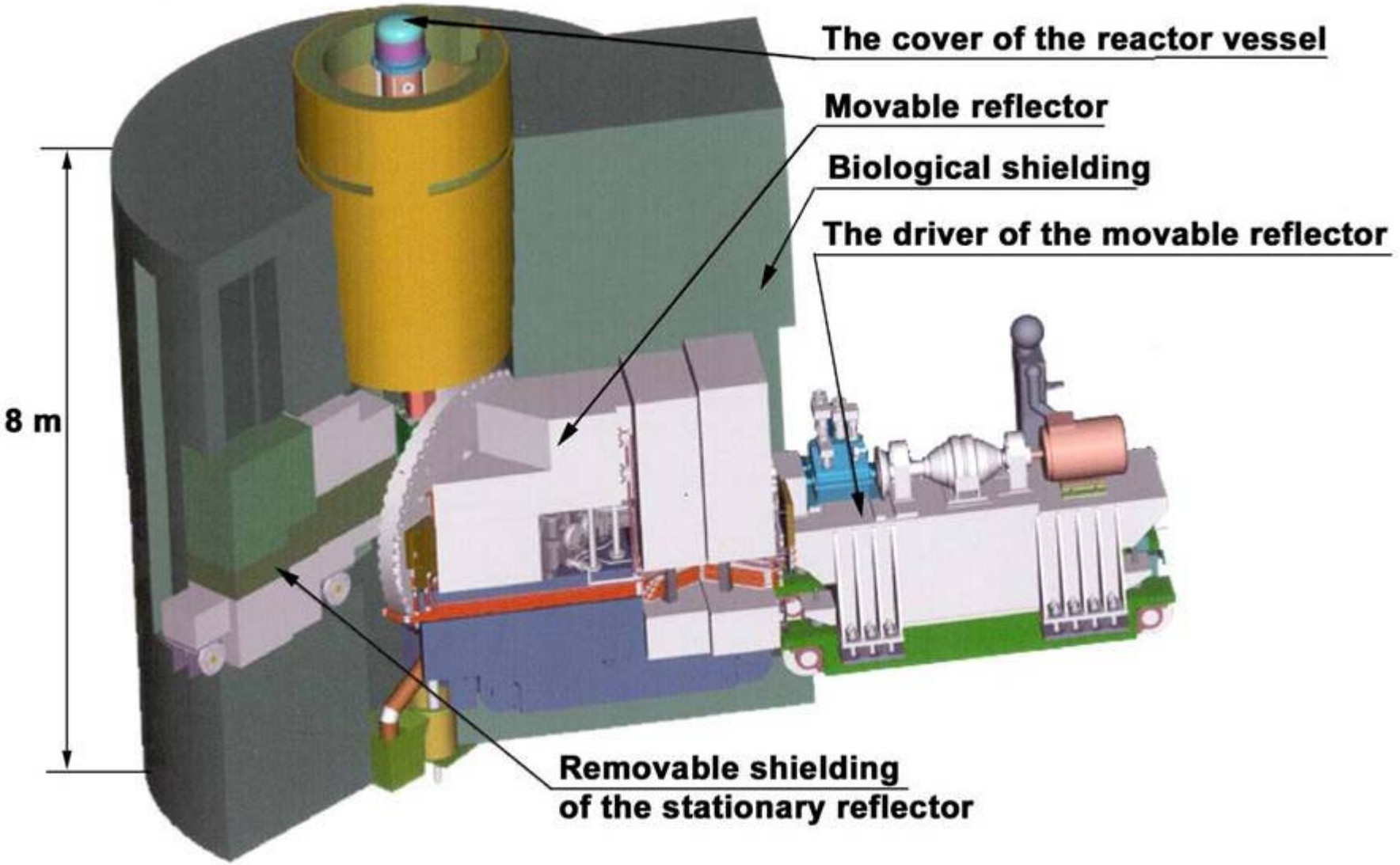
IBR-2M



IBR-2 REFURBISHMENT IN 2002

The main tasks

1. Movable reflector MR-3 : completion and test assembling
   => delay ~ 2 months, not critical

2. New fuel loading (PuO_2 pellets)
   Manufacturing technology completion => *OK*

3. Control, protection and emergency systems
   Technical project => *in progress, OK*

4. Electronics for the reactor control and protection system : has to be produced by The Institute for Atomic Energy (Swerk, Poland), but is delayed by Polish partner.
   The status: Technical Proposal is received in May 2002, price – unacceptable, the negotiations continue.

5. New reactor vessel *design* –(The Research and Design Institute for Power Engineering, Moscow) => to be completed in 2002, OK

6. The present reactor vessel dismantling
   The project is near completion

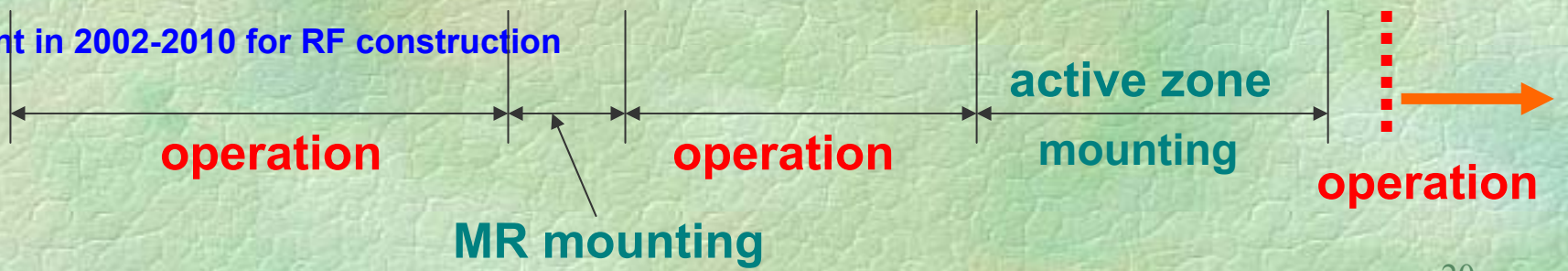
7. Refrigerator Facility (RF)
   The project => in progress ("Heliummash" plant, Moscow).
   The RF is planned to be constructed in commissioned to the end of 2009.

Financing Plan of the IBR-2 Refurbishment

plan / fact (k$)

Year	1995-99 fact	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
JINR	550	*192* 193	*490* (210*) 233	*250*	*250*	*250*	*100*	*240*	*400*	*300*	*300*	*100*	*3630*
Ministry of Atomic Energy	0	*300* 342	300 301	*450*	*450*	*470*	*400*	*300*	*300*	*300*	*300*	*0*	*3570*
Total:	550	*492* 535	790 534	*700*	*700*	*720*	*500*	*540*	*700*	*600*	*600*	*100*	*7200*

*) To be spent in 2002-2010 for RF construction



Flerov Laboratory of Nuclear Reactions

U400 & U400M

U400

Experiments on the synthesis of the element 118 in reaction:

^{48}Ca (260 MeV) + ^{249}Cf (0.23 mg/cm^2) => $^{293}118$ + 4n

Experiment started on 22.02.2002,

Ion beam on the target $4 \cdot 10^{12}$ ions/s,

Planned beam dose $2 \cdot 10^{19}$ ions (~1400 h).

U400M

Experiments with cryogenic ^{2}H &,^{3}H targets on the search for resonances in ^{5}H and ^{7}H in reactions:

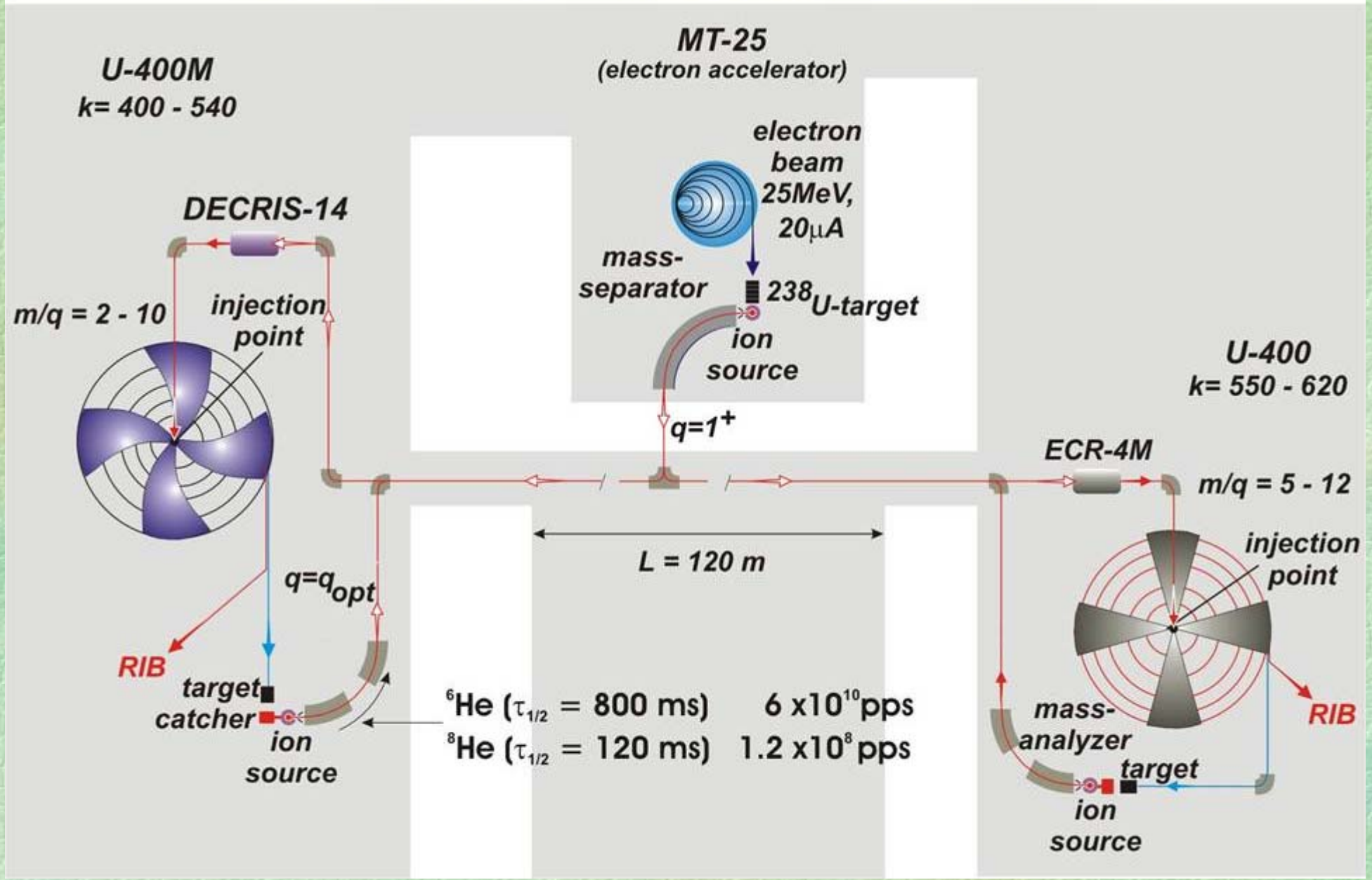
1. $^{6}He + {}^{2}H \rightarrow {}^{5}H + {}^{3}He$
Experiment started on 25.03.2002 and finished on 30.04.2002,
Average current of ^{6}He beam on the target $1.5 \cdot 10^{5}$ ions/s,
Obtained beam dose ($\sigma \cong 5$ μb/sr) $3.0 \cdot 10^{11}$ ions.

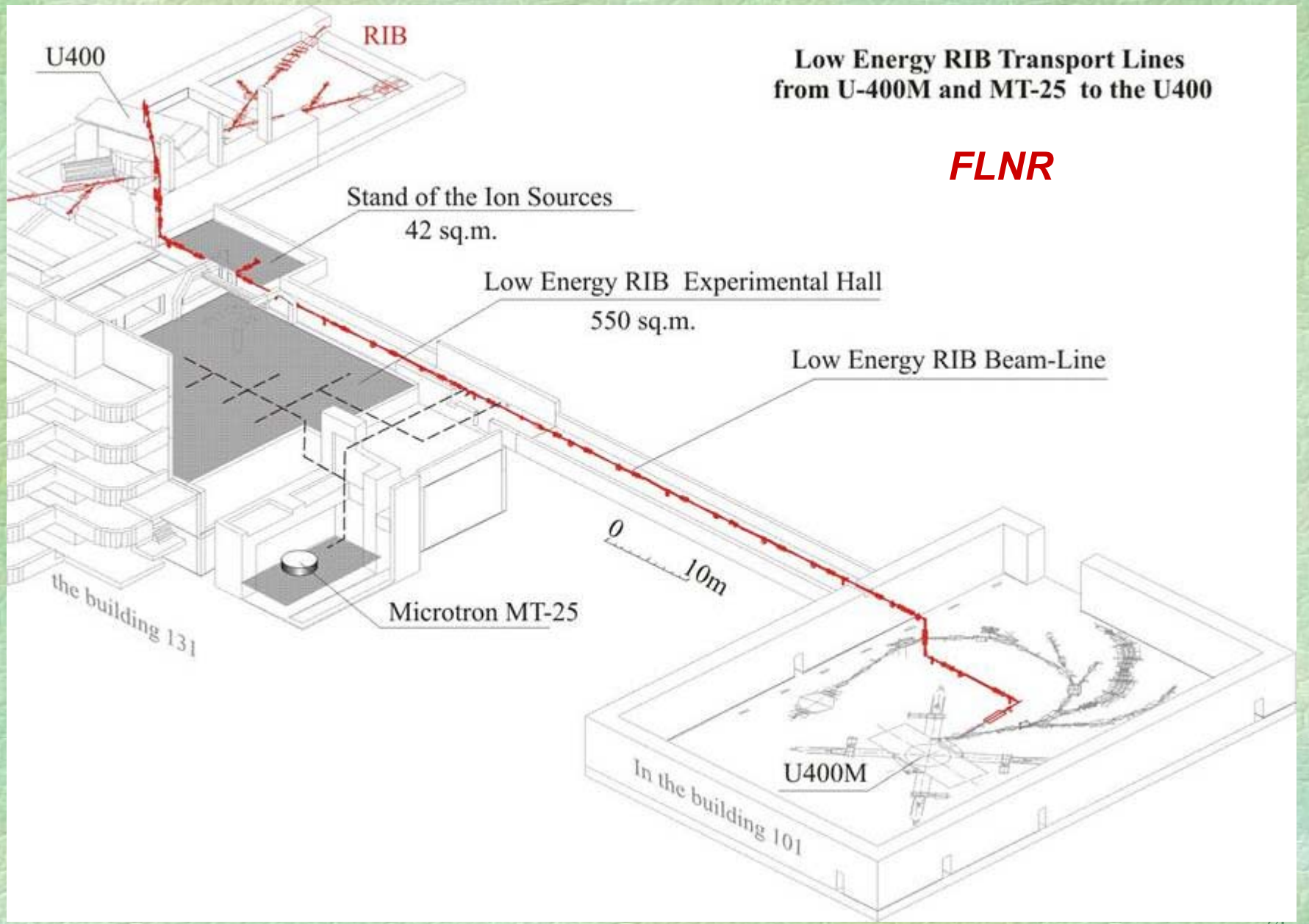
2. $^{8}He + {}^{2}H \rightarrow {}^{7}H + {}^{3}He$
Experiment will run in June, 2002,
Average current of ^{8}He beam on the target $1 \cdot 10^{4}$ ions/s,
Planned beam dose ($\sigma \cong 1$ μb/sr)$2.0 \cdot 10^{10}$ ions.

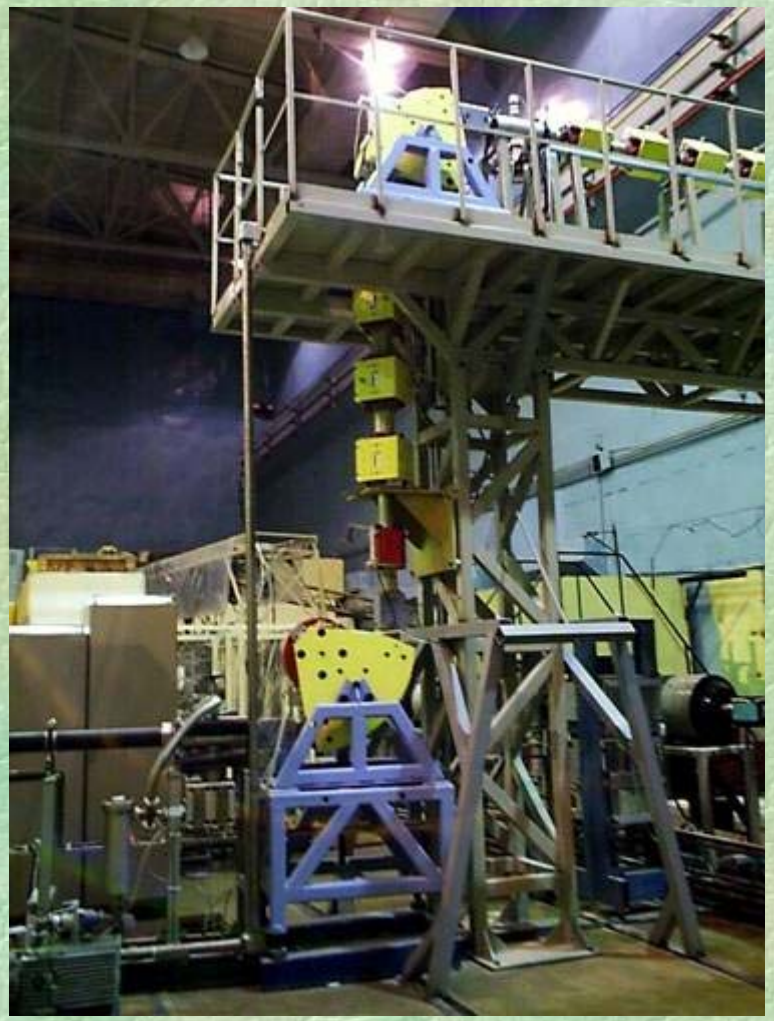
3. Reaction $^{3}H + {}^{3}H \rightarrow p + {}^{5}H$
will be studied in December with facility DEMON arriving at this time.

FLNR

Concept of the RIB Accelerator Complex of the FLNR (JINR)




Low Energy RIB Transport Lines
from U-400M and MT-25 to the U400
FLNR
U400
RIB
Stand of the Ion Sources
42 sq.m.
Low Energy RIB Experimental Hall
550 sq.m.
Low Energy RIB Beam-Line
0
10m
Microtron MT-25
the building 131
In the building 101
U400M



DRIBS transfer channel

First results at DRIBS

1.

Primary beam from U400M:

^{11}B 34 MeV/u 0.02 pμA·

Secondary beam from U400:

^{6}He (0.8 s) 16 MeV/u $2 \cdot 10^{6}$ p/s

2.

Primary beam from U400M:

^{7}Li 32 MeV/u 0.02 pμA·

Secondary beam from U400:

^{6}He (0.8 s) 16 MeV/u $1 \cdot 10^{7}$ p/s

It corresponds to $5 \cdot 10^{9}$ p/s

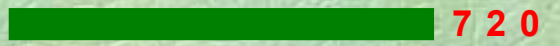
when ^{7}Li beam is 10 pμA·

(Project value => $9 \cdot 10^{9}$)

PHASOTRON OPERATION

Dzhelepov Laboratory for Nuclear Problems

PLAN 2002
(hours)



Medicine	720
DUBTO (pion – nucleon interaction)	140
SAD ("Energy Amplifier")	100
YASNAPP (Nuclear Spectroscopy)	150
Machine development	100
μ-catalysis	250
FAMILON (search for muon rare decay channels)	250
Total operation time	1710

Phasotron channels up grade

- Two new target stations:

Pion beam, 200 – 400 MeV, 25^0 - 30^0

Low energy pion beam, 110^0 - 120^0

- Vacuum channels
- Small proton beam spot on the target

Expected results:

- Pion beam intensity enhancement:

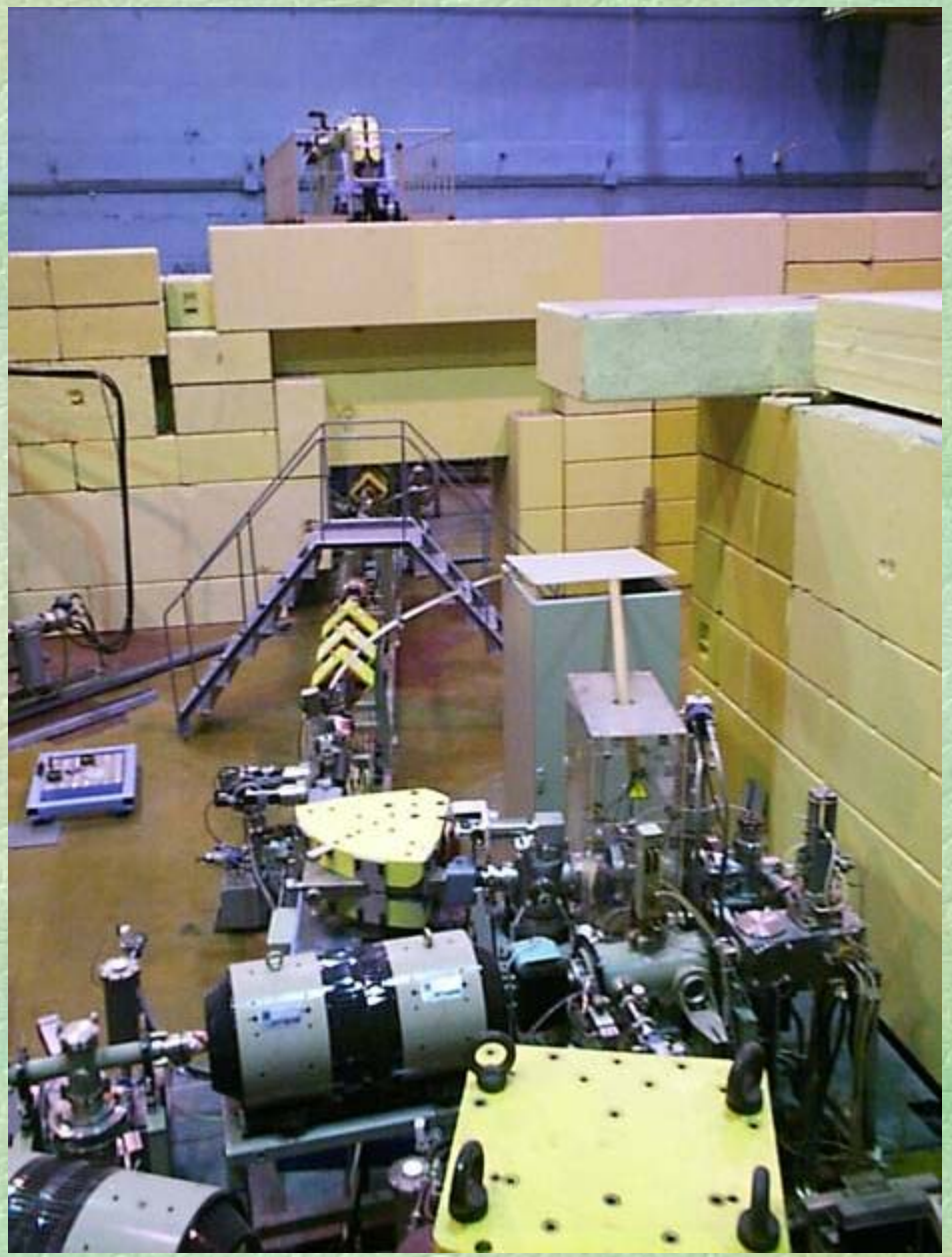
15 – 50 MeV => by 3 – 5 times (10^5 => 10^7 s^{-1})

200 – 400 MeV => by 2 – 20 times ($3 \cdot 10^7$ s^{-1})

- Improvement of the radiation condition at the target area

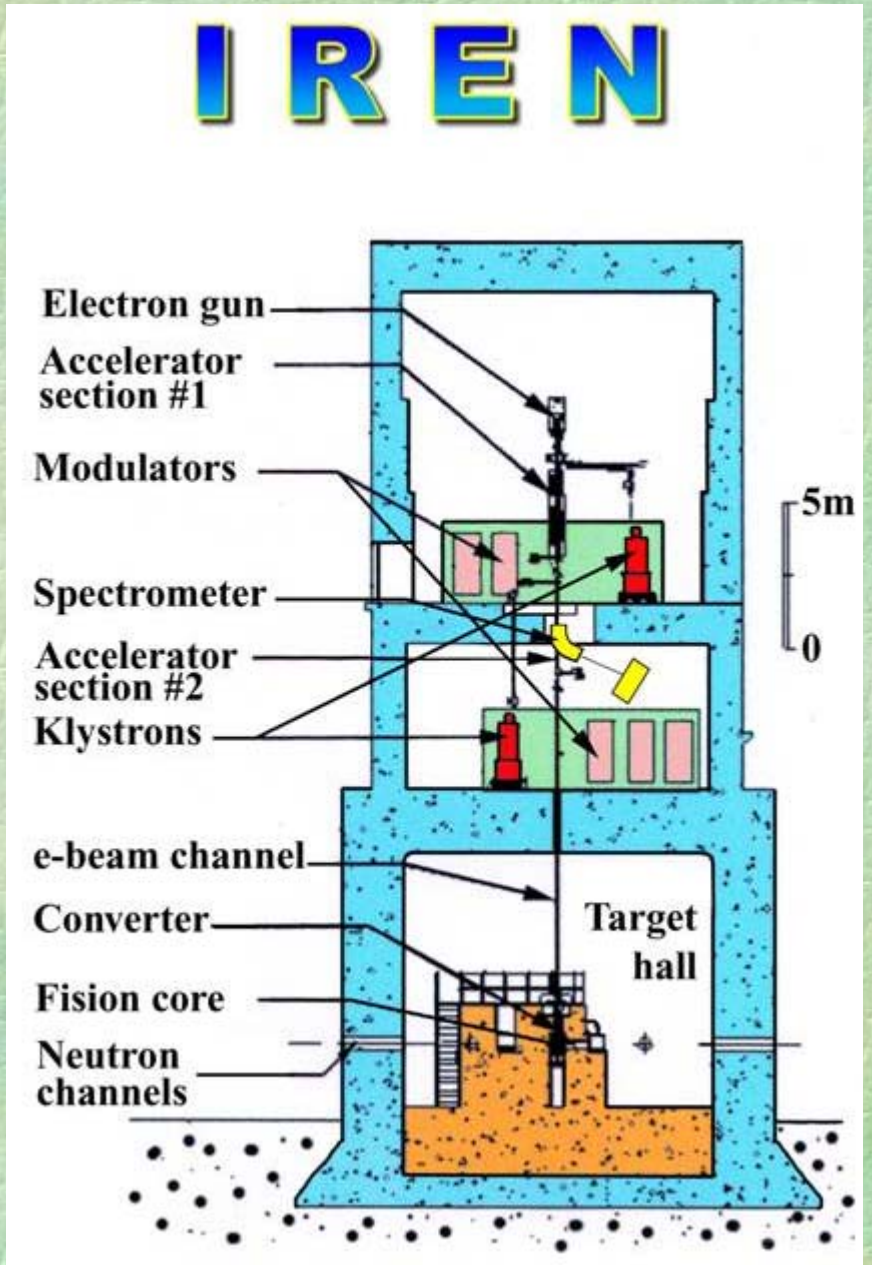
- Simultaneous work of several user groups

Phasotron Target Area

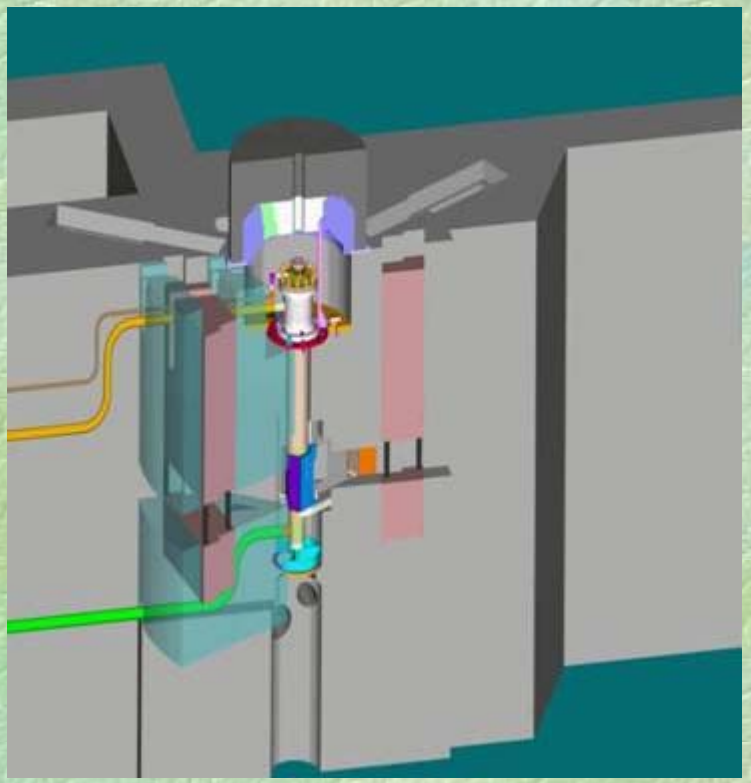


Phasotron beam transfer line

Frank Laboratory for Neutron Physics & Laboratory for Particle Physics



IREN Source Perspectives



Main Parameters:

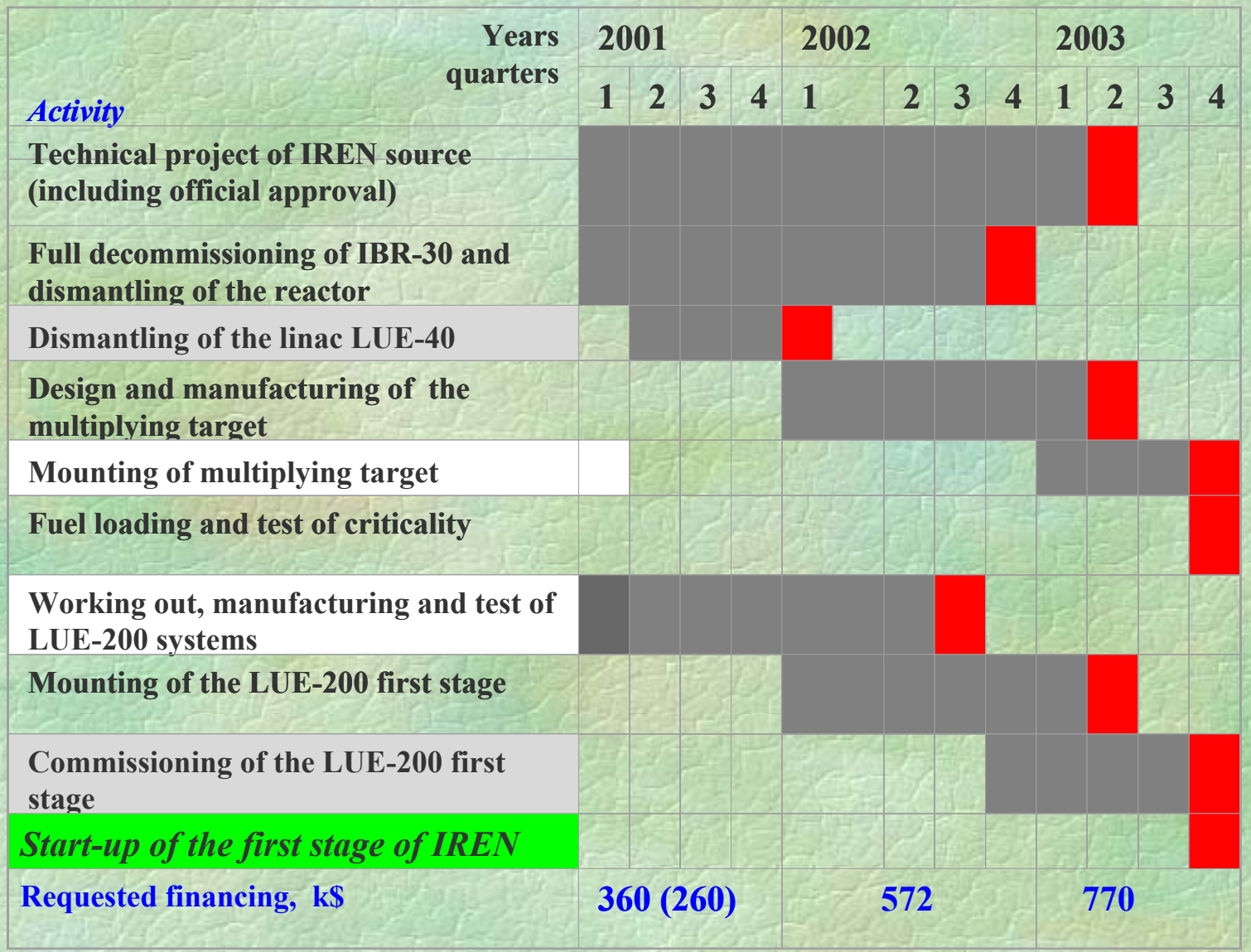
Electron beam energy	200 MeV
Neutron flux	10^{15} n/s
Neutron pulse duration	400 ns
Repetition rate	150Hz

2002	2003	2004	2005	2006-2009	
Creation and start, first stage					1572 K$
			Full completion		350 K$
	Modernization of spectrometers				950 K$
				Data taking	760 K$

LPP

Test of klystron in working regime (March 2002)

Time-table and plan of financing of the IREN project for years 2001-2003



Approved total cost of the project 3740 k$

Invested in 1994 - 2001 - 1830 k$

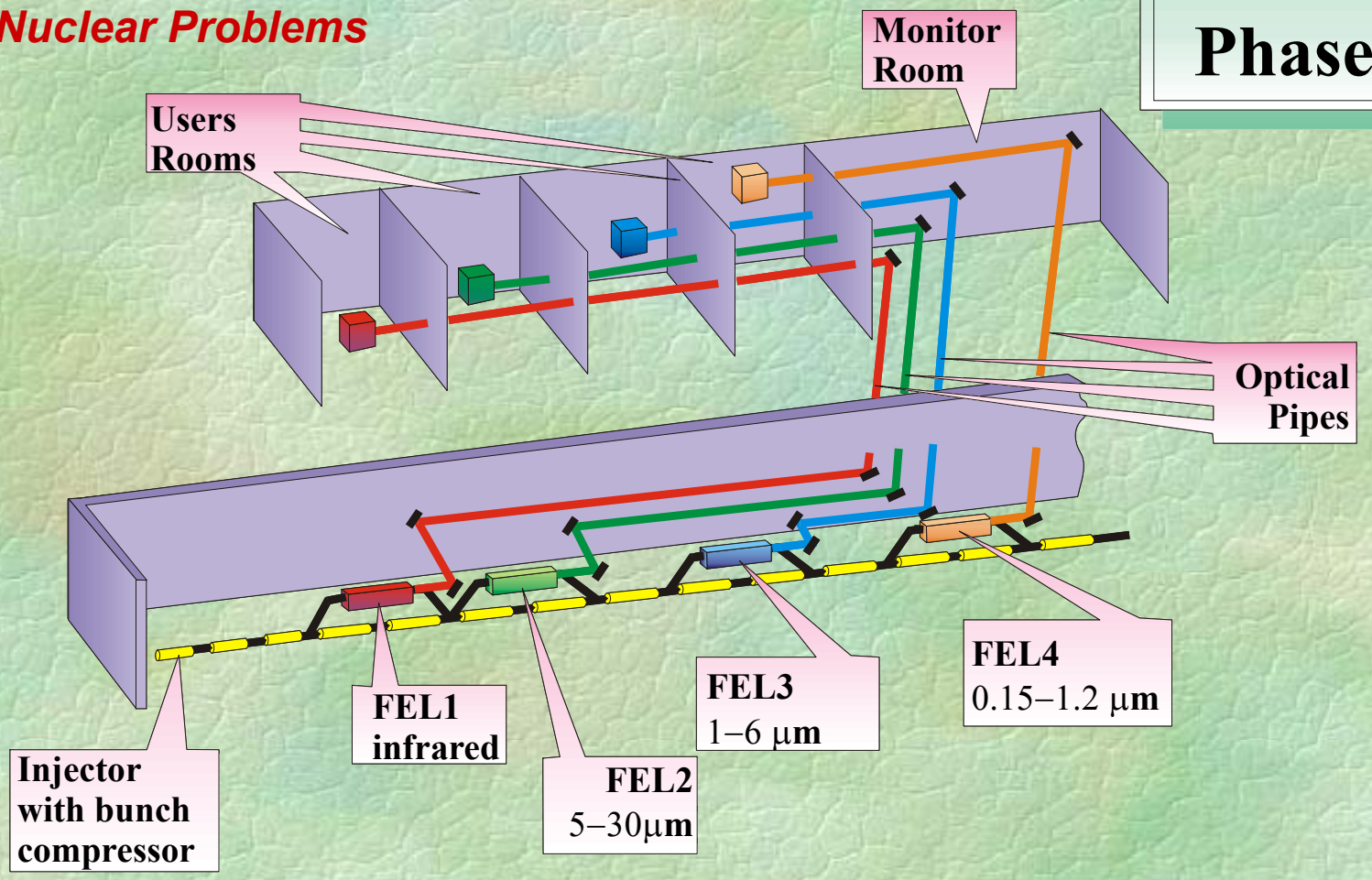
Planned investments in 2004 - 430 k$

IREN
Main Goals in 2002

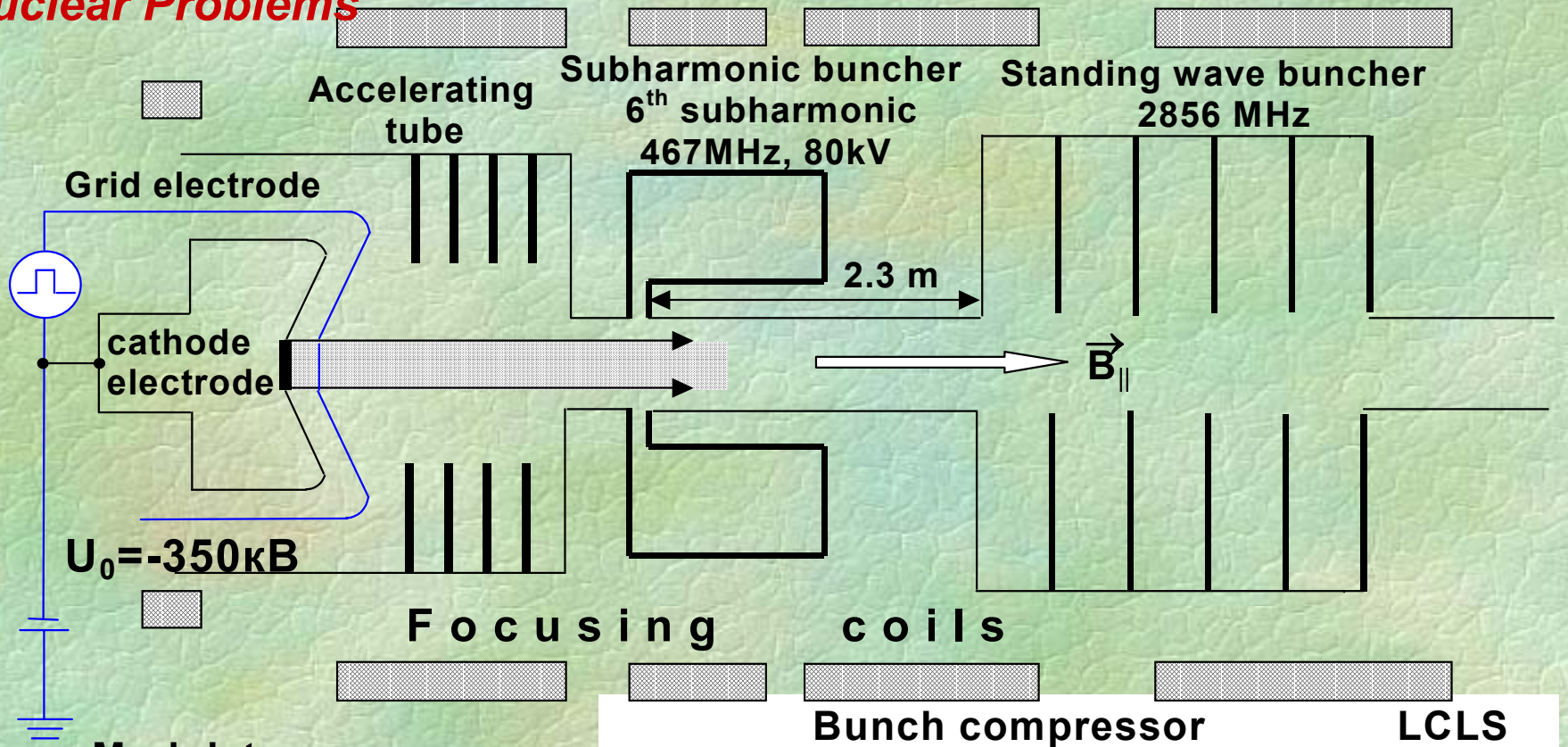
- Completion of the Technical project of IREN source
- Full decommissioning of IBR-30
- Start of LUE-200 mounting => October 2002
- Technical design and start of the target manufacturing

Laboratory for Particle Physics
&
Dzhelepov Laboratory
for Nuclear Problems

DELSY Phase I



INJECTOR

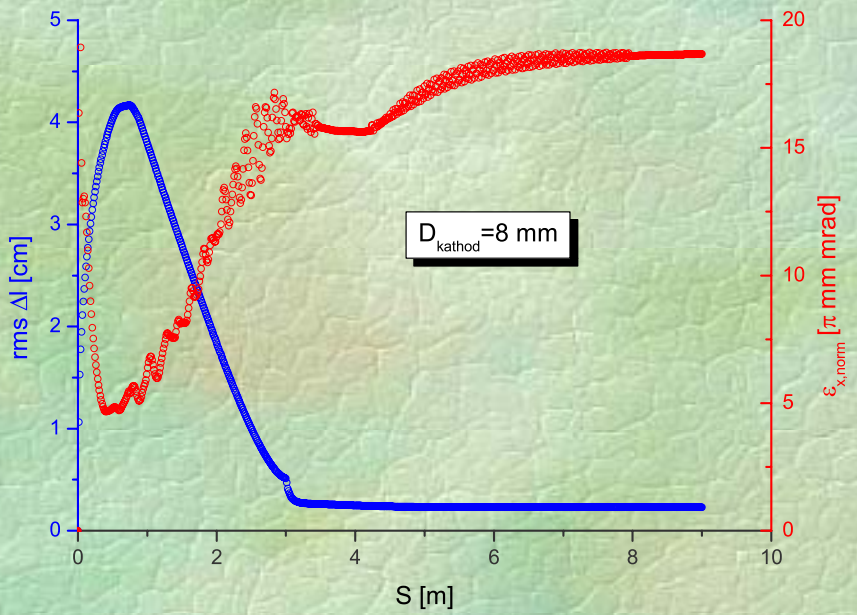


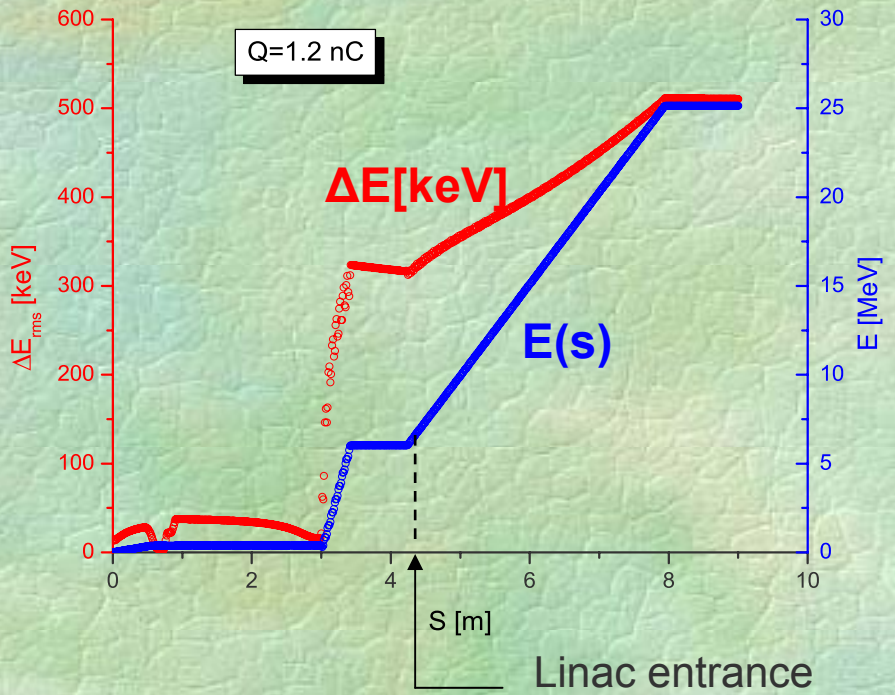
Modulator
(grid pulser)
0.5 ns 22.3125 MHz,
150 V, 24μs, 50 Hz

	Bunch compressor	LCLS
Bunch duration, ps	500 ⇒10	0.23
Bunch length, cm	12.1⇒ 0.3	0.07
Electron energy, MeV	0.35⇒ 5.0	15 GeV
Peak current, A	2.5 ⇒ 250	3.4 kA
Bunch charge, nC	1.2 ⇒1.2	0.8

Bunch dynamics in the linac injector

Q= 1.2 nC

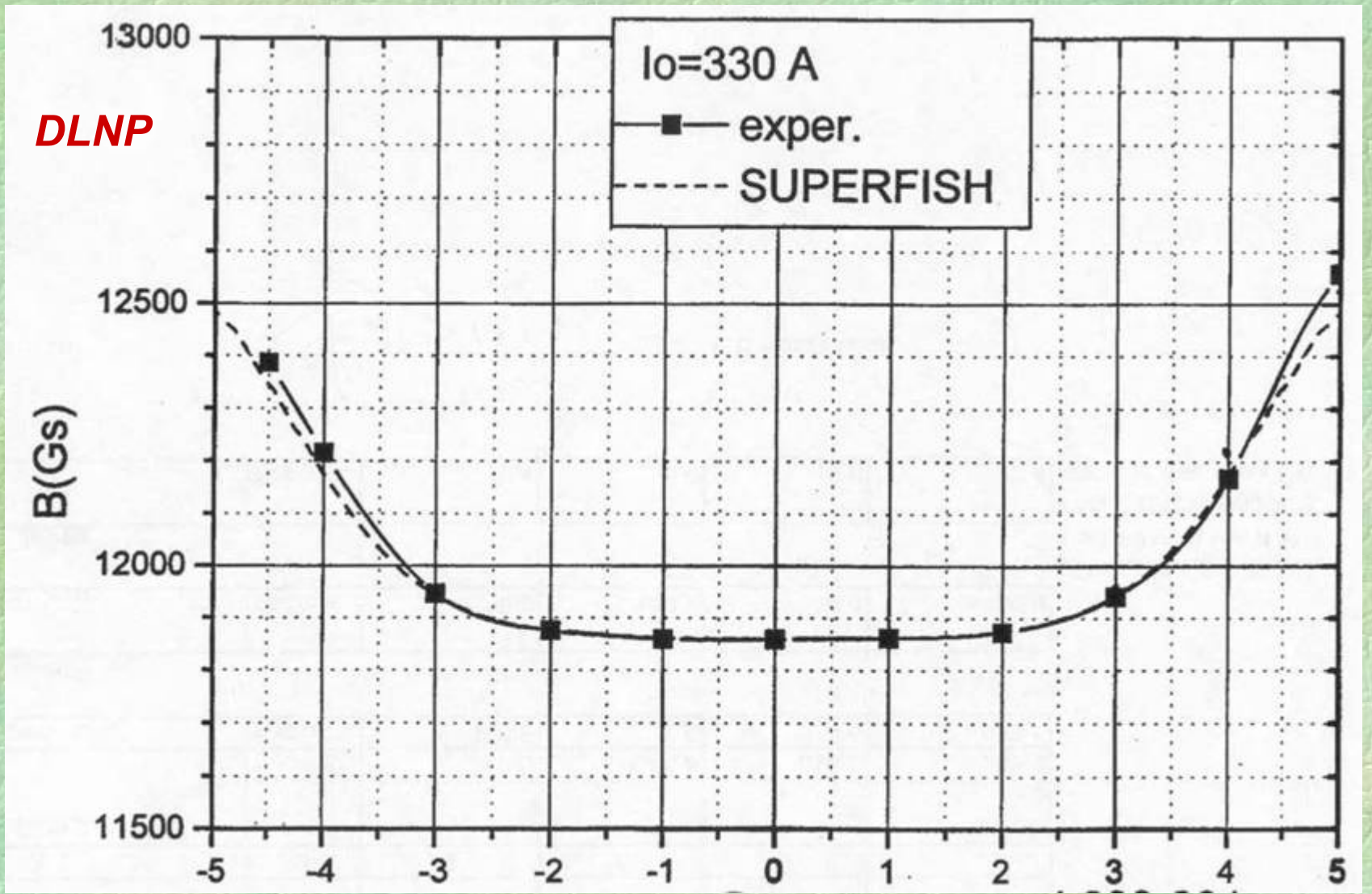




DLNP

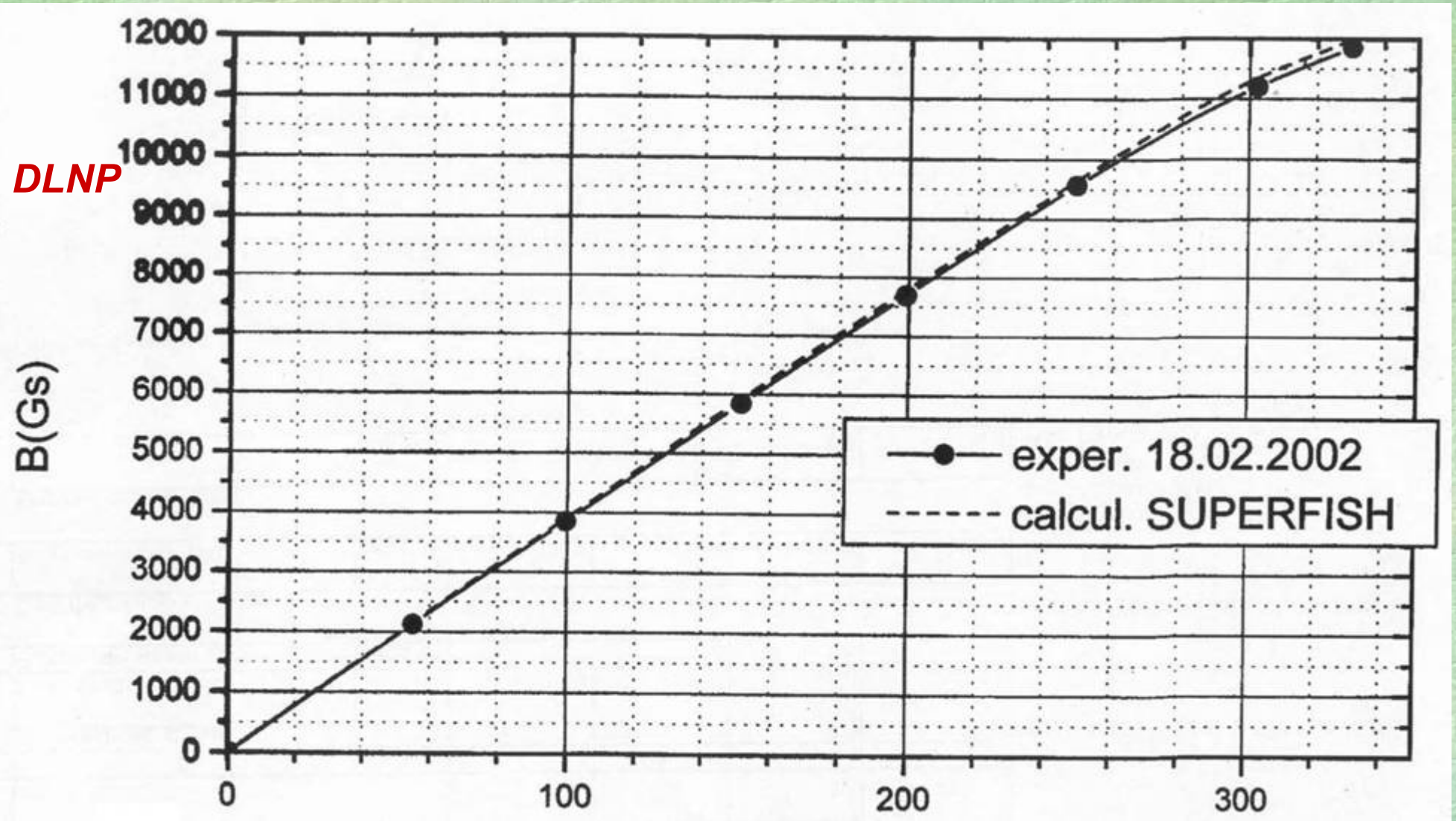
Test of the AmPS Dipoles Modified for the DELSY Ring

April 2002



Dipole upgrade: B ⇒ 12 kG

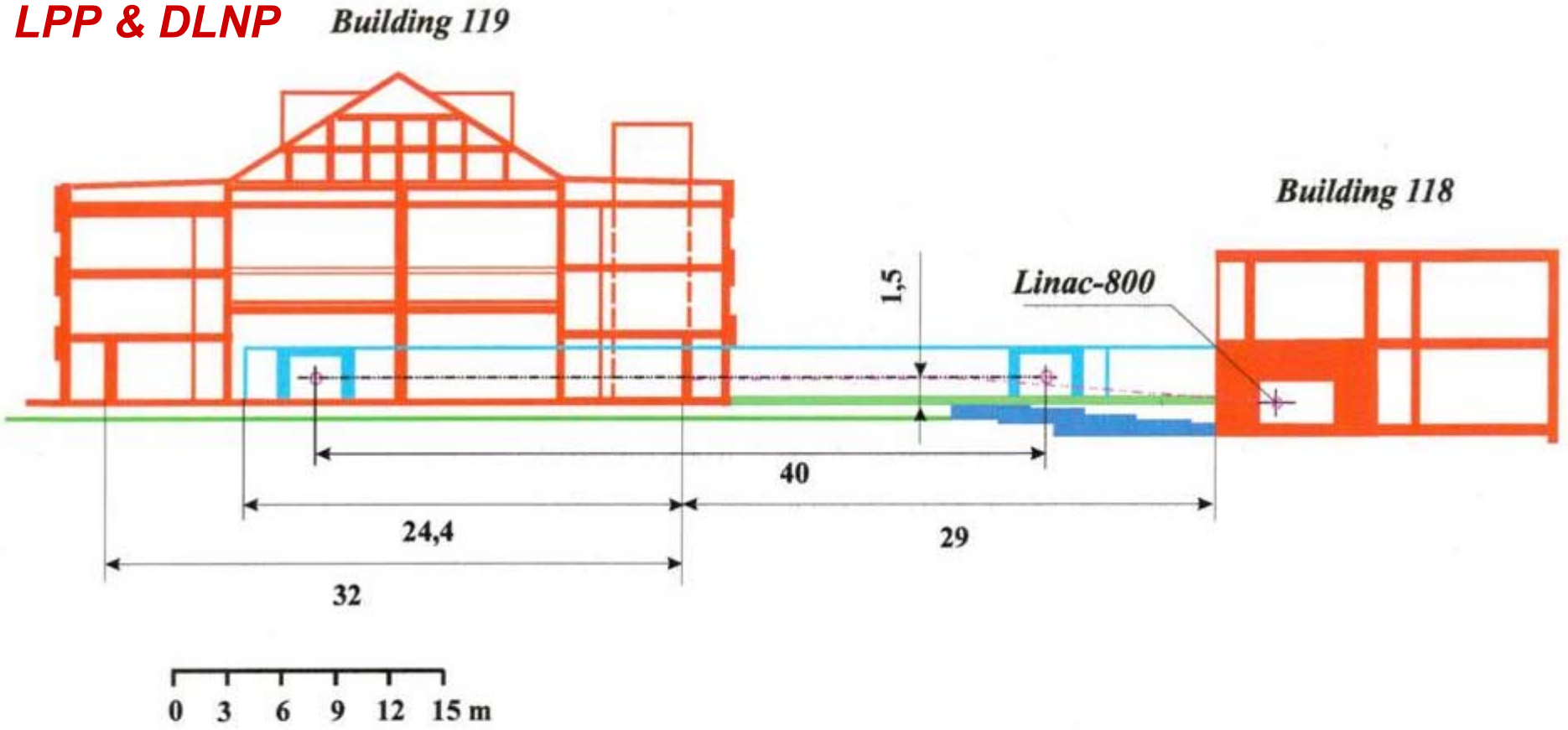
DLNP



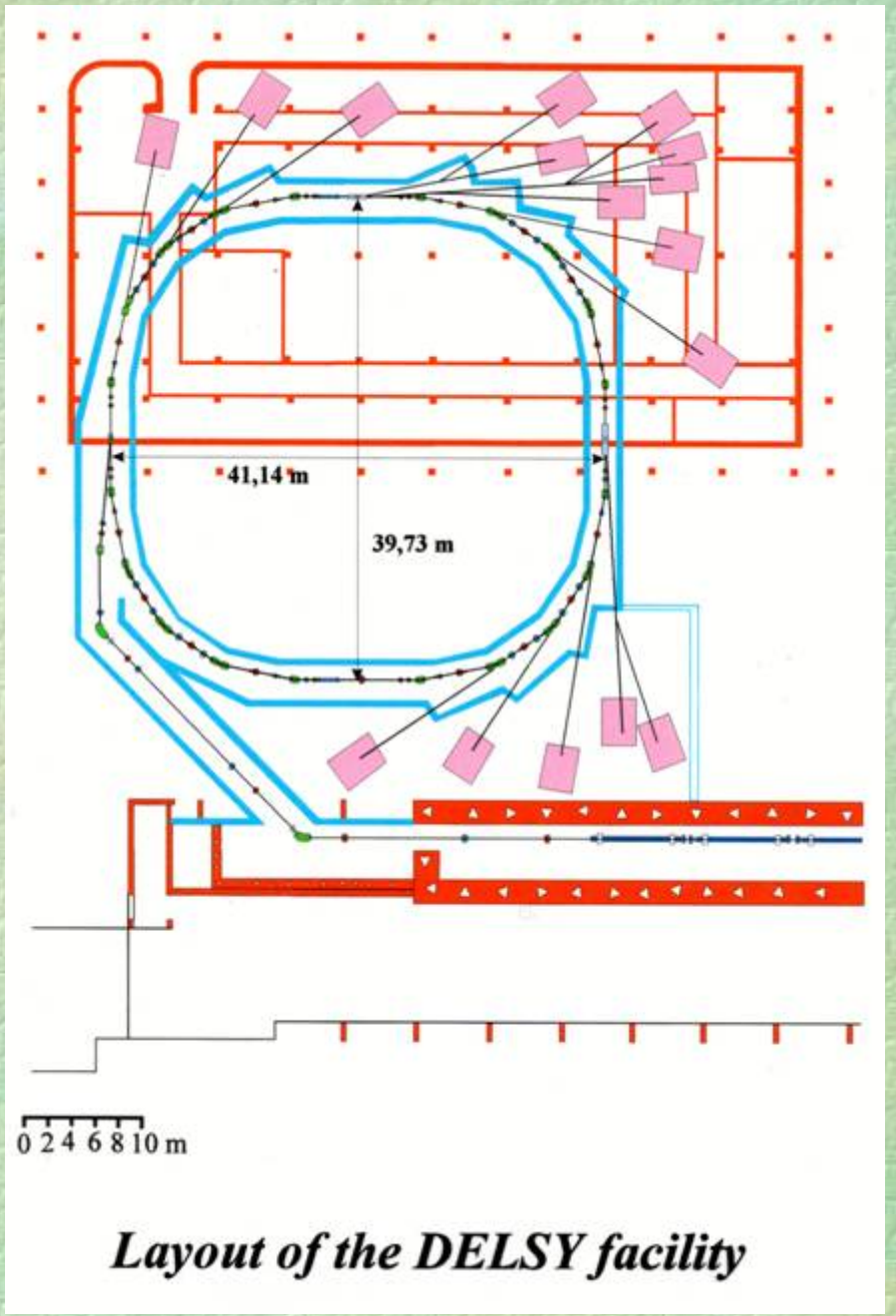
I (A)

bi-004

Dipole upgrade: B ⇒ 12 kG

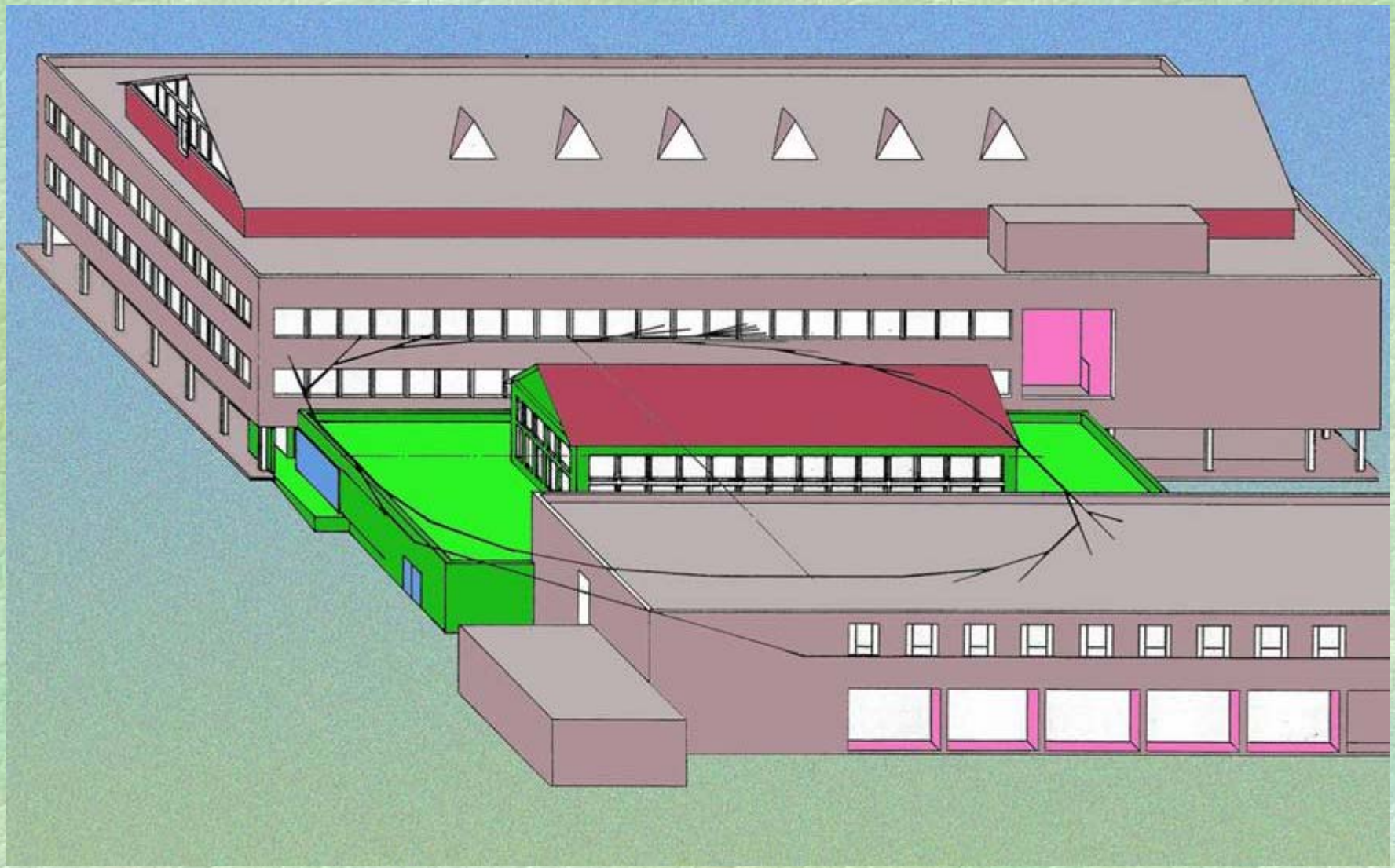


The buildings of the DELSY facility



Layout of the DELSY facility

DELSY Facility Buildings



30 May 2002

The DELSY ring layout is completed

Irina Titkova & Vladimir Bykovsky, May 2002

Cost Estimate and Tentative Schedule of the DELSY Project Realization

Phase I & Phase II

	Work	Cost (k$)	Funding distribution over years			
			2002	2003	2004	2005
	Phase I "Linac-800 & FELs"					
1	Preparation of the Buildng #118	140	80	60	-	-
2	Roof reparation of the Bldng #118	70	-	70	-	-
3	Linac-800 assembling and commissioning	250	50	200	-	-
4	IR FEL	530	10	500	20	-
5	VUV FEL	800	-	100	700	-
	Sum I: 1790 (Linac – 460, FELs – 1330)		140	930	720	-
	Phase II – Storage ring					
1	Technical project (GSPI)	70	8	62	-	-
2	Ring tunnel construction	2430	-	-	1200	1230
3	Ring assembling	450	-	-	120	330
4	Assembling of power supplies and control systems	300	-	-	165	135
5	Wiggler, undulator	600	-	-	200	400
	Sum II:	3850	8	62	1685	2095
	Total Sum:	5640	148	992	2405	2095

Construction of the ring aside from the Buildings ##118 and 119 requires additional funding of 970 k$

RECOMMENDATIONS ON THE DELSY PROJECT

taken at the meeting of the JINR Directorate on 19 March 2002

JINR participants: V. Kadyshevsky, A. Sissakian, Ts. .Vylov, I. Meshkov, V. Katrasev, V. Itkis, V. Aksenov, N. Russakovich, V. Brudanin, E. Syresin, E. Perelshtein, I. Ivanov, G. Arzumanyan, N. Balalykin, I. Titkova.

Invited experts: G. Kulipanov, A. Lebedev, E. Levichev, V. Mikhailin.

Agenda items: Report on the DELSY project by JINR Chief Engineer I. Meshkov; presentations by invited experts G. Kulipanov, A. Lebedev, E. Levichev, V. Mikhailin, by JINR leading specialists E. Perelshtein, V. Aksenov, I. Ivanov et al., and by members of the JINR Directorate.

RECOMMENDATIONS

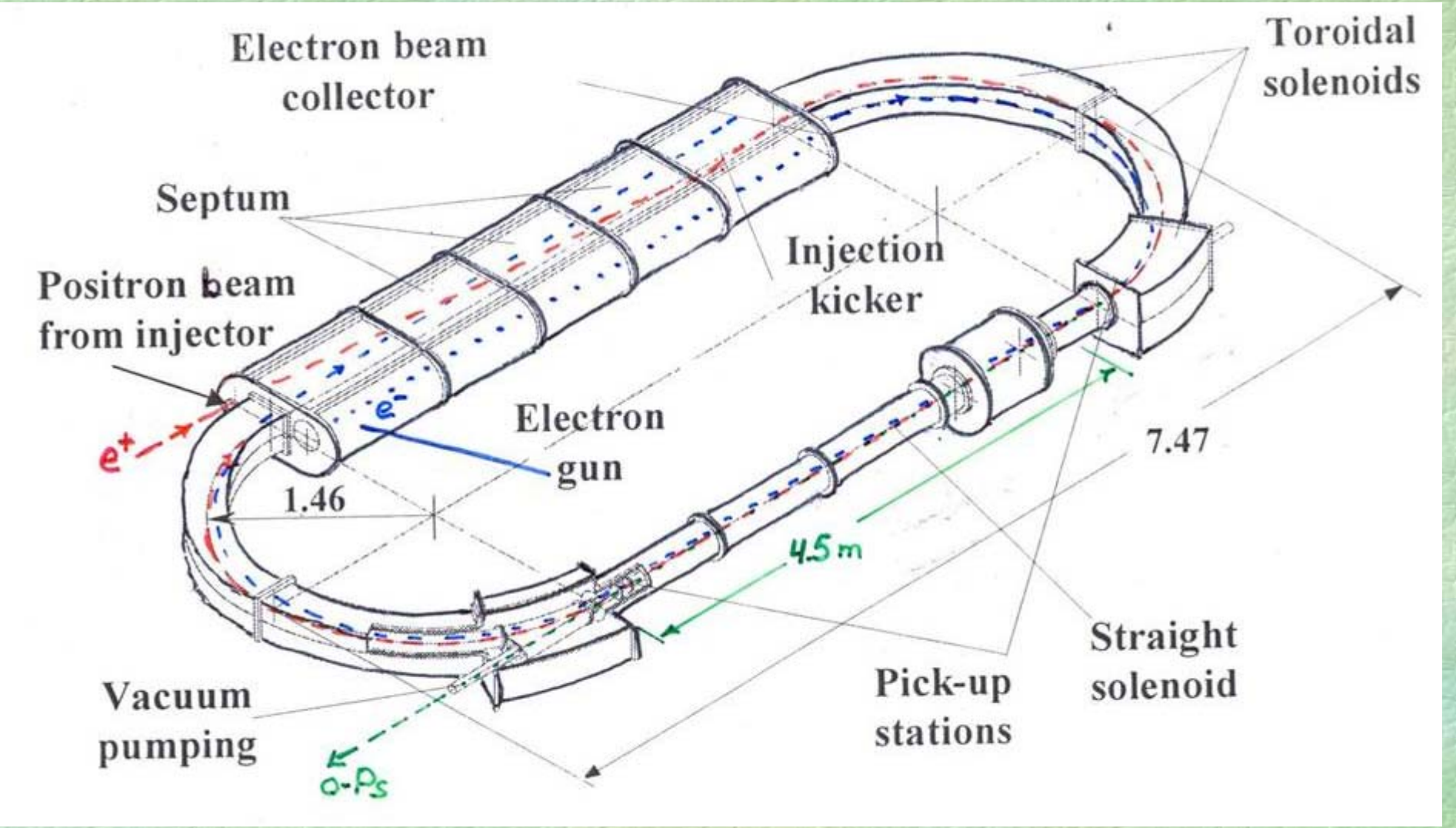
- The DELSY project opens a new important perspective direction of JINR's further development;
- The project is technically feasible and provides a basis for preparing a Technical Proposal taking into account the remarks given by the experts;
- Of special importance, in particular for educational purposes, is Phase 2 of the DELSY project - the storage ring;
- It is recommended to establish a Scientific Coordination Committee (or a Scientific and Technical Committee) on the DELSY project and to ask all the invited experts to participate in it;
- The JINR Directorate should continue the efforts towards finding the necessary resources for the project realization.

V. Kadyshevsky
Chairman of the meeting

I. Titkova
Secretary

Low Energy Positron Toroidal Accumulator Particle

Dzhelepov Laboratory for Nuclear Problems



Physics at LEPTA

- **Electron cooling of positrons**
- **Physics of Positronium**
  - e^+e^- recombination
  - O-Ps and p-Ps life time
  - Rare and forbidden decay channels study
  - Positronium spectroscopy
- **e^+ / e^- charge difference =>** the first and foremost experiment
- **Antihydrogen generation in-flight => CPT theorem test (future development)**
- **High intense beam acceleration and circulation => to electron cooling with circulating electron beam in GeV particle energy range**

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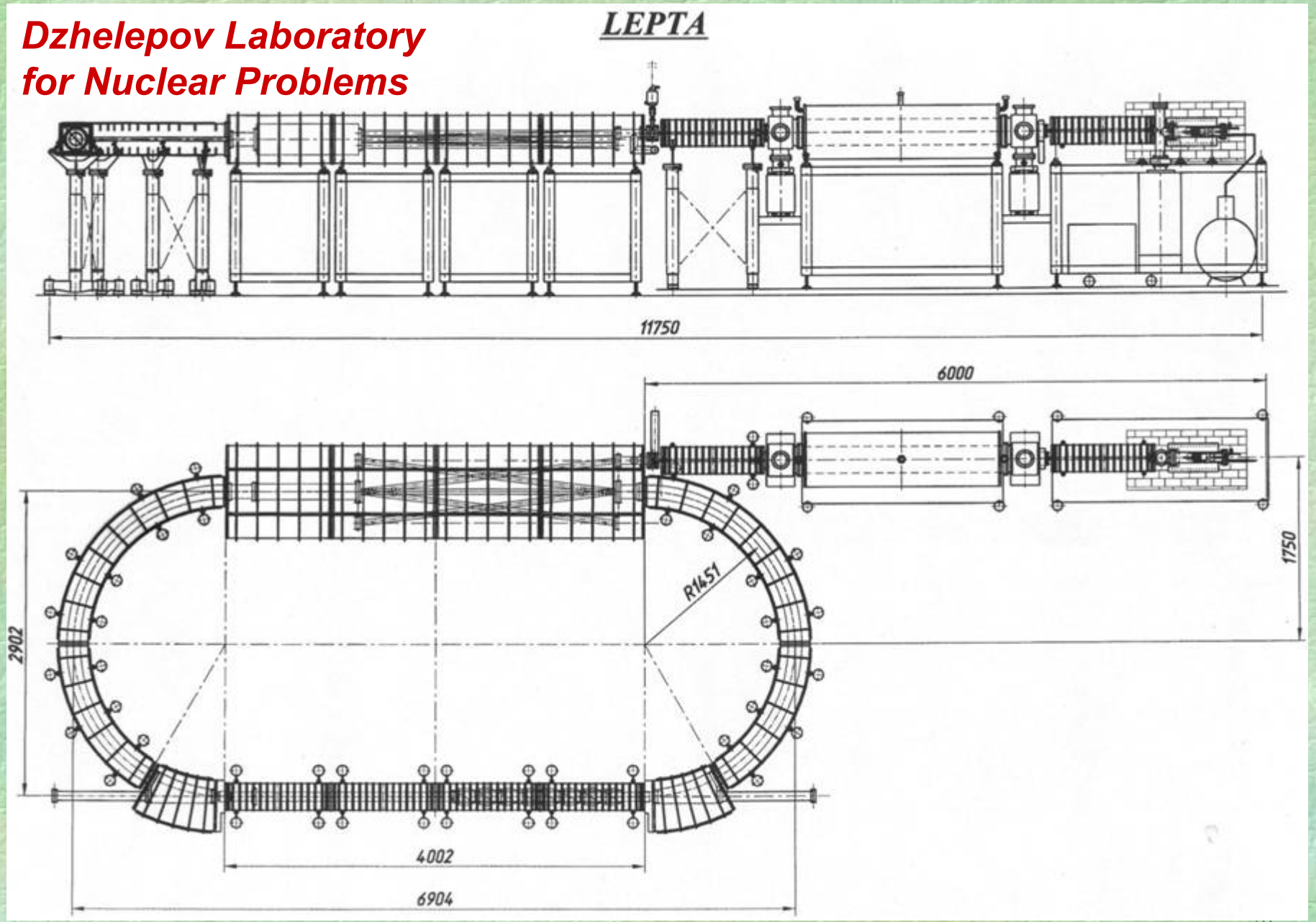
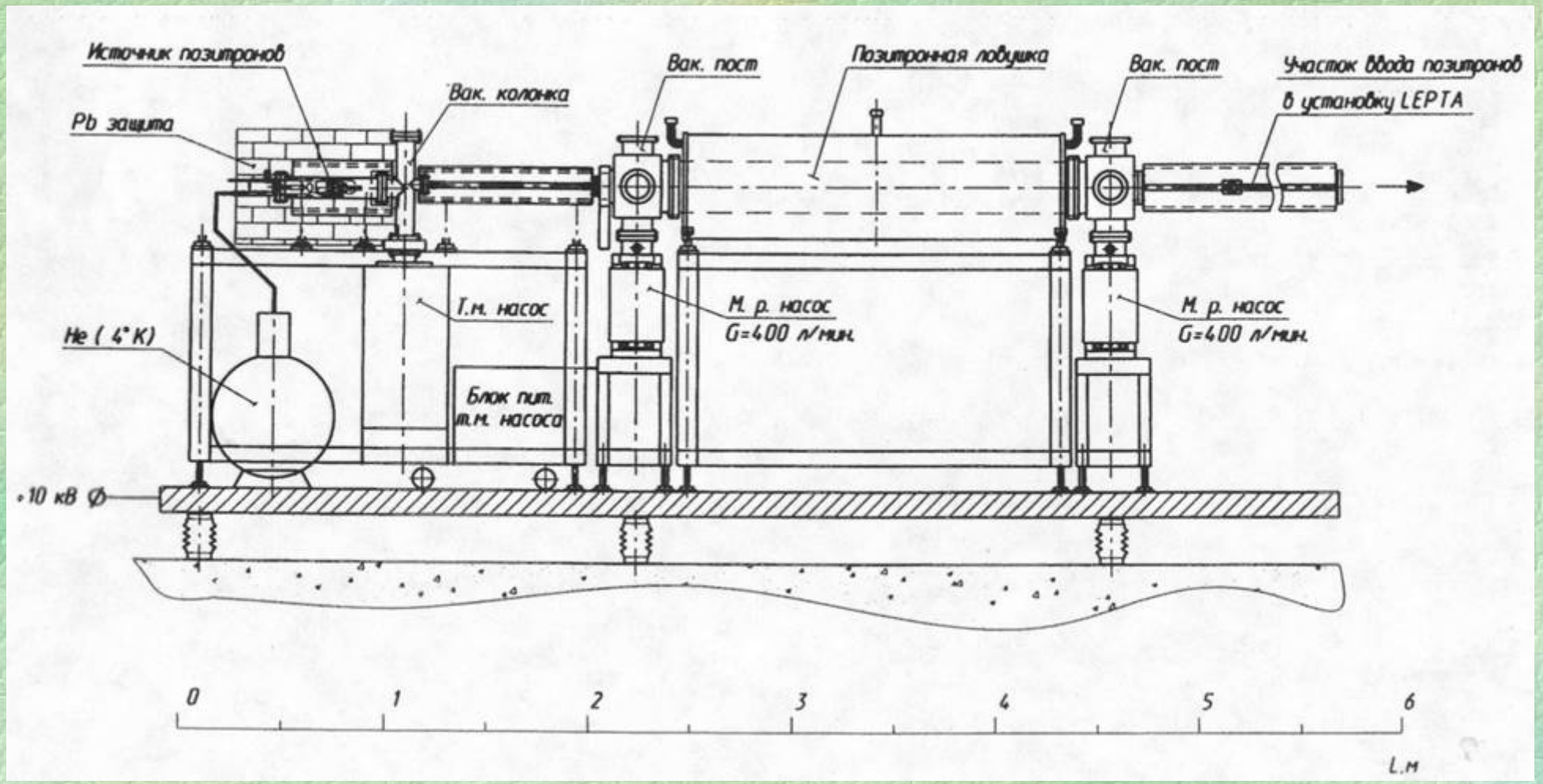
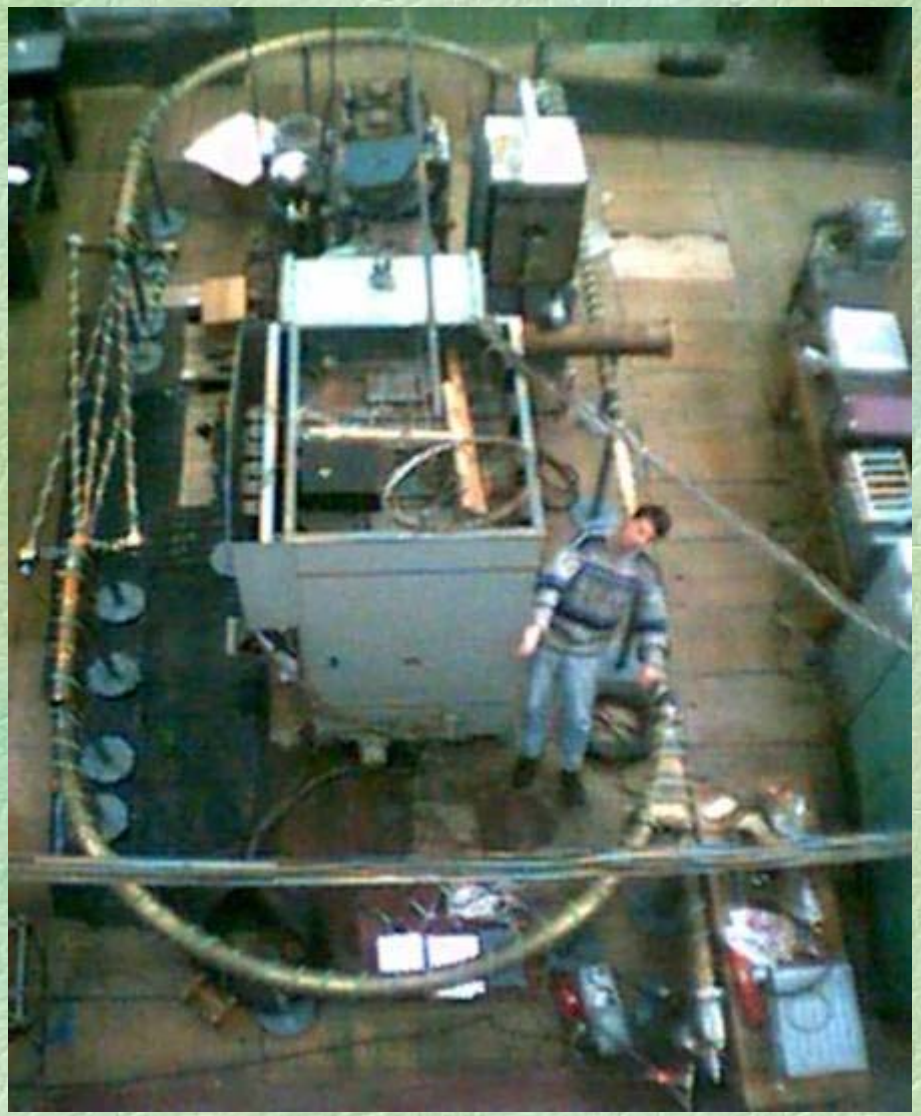


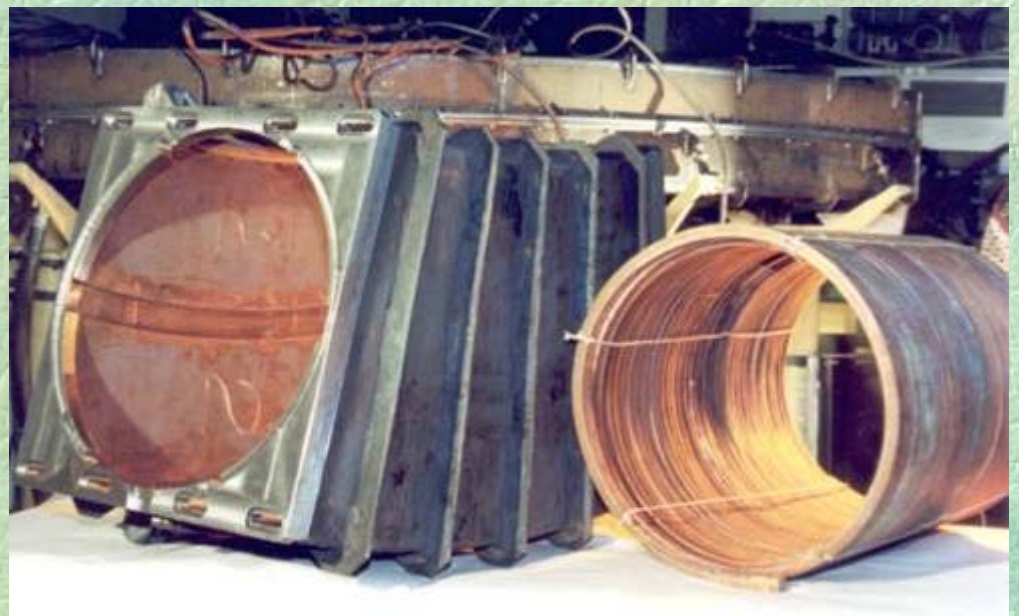
Positron injector





July 2000

December 2001



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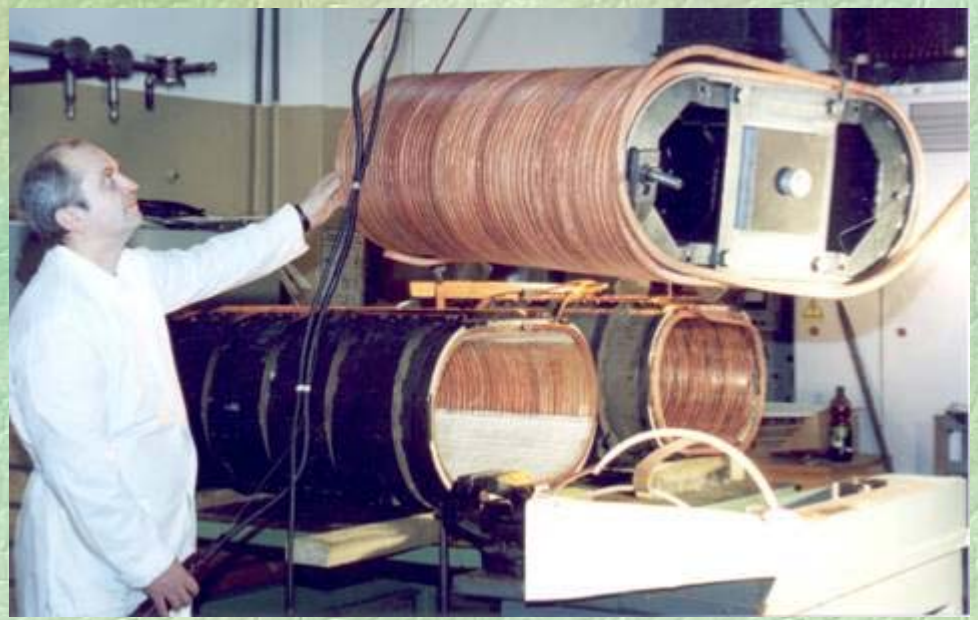
December 2001

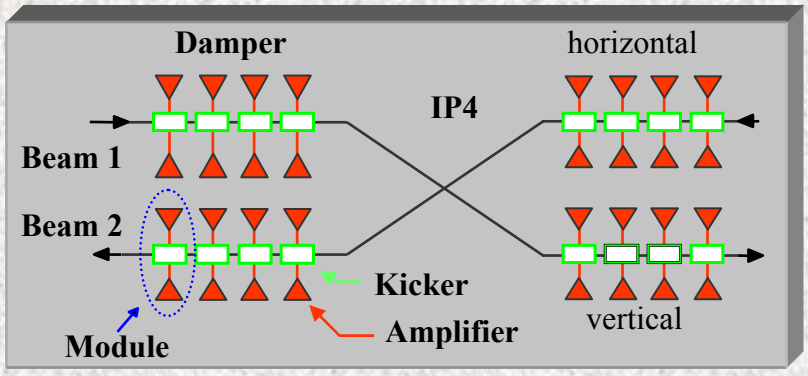


LEPTA Ring

December 2001

LHC Damper *(system parameters)*

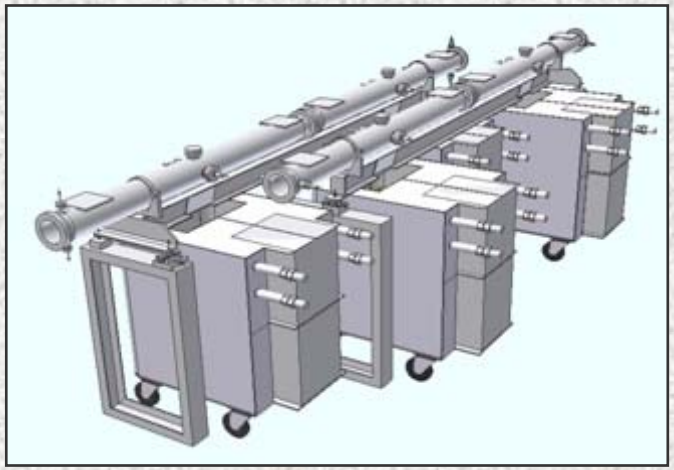
System structure



Dynamics parameters

Injection momentum 450 GeV/c	
Errors & ripple (β = 183 m)	**4 mm**
Resistive wall growth time	**14 ms**
Decoherence time	**68 ms**
tolerable emittance growth	**2.5 %**
overall damping time	**4.7 ms**

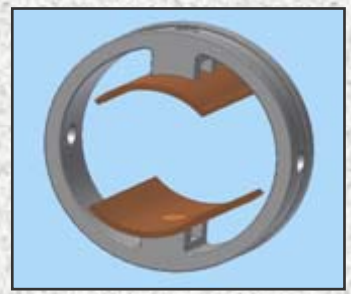
Damper layout

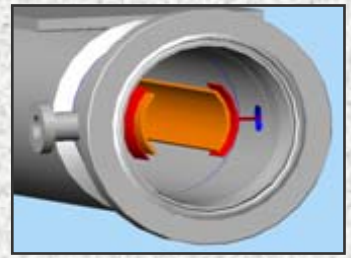


Damper parameters

Amplitude	**± 7.5 kV**
Average power per one tetrode	**16 kW**
Bandwidth (full signal)	**10^{-3} ÷ 1 MHz**
(6dB/oct)	**1 ÷ 20 МГц**
Rise time, 10-90%,	**350 ns**
1-99%,	**720 ns**

LHC Damper *(status 2002)*





Last investigations:

impedance and HOM problems in the kicker

Solutions:

- **new design of the electrodes' support (full ceramic)**
- **additional capacitive couplers for energy evacuation**

Manufacturing:

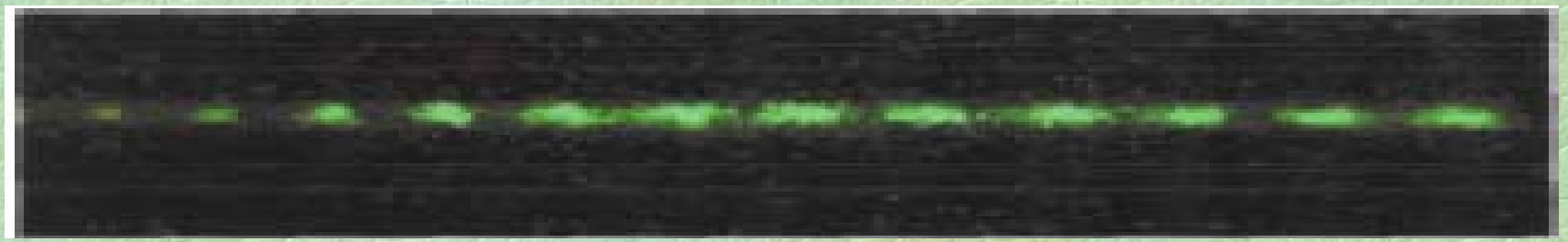
- **Last version of the drawings of kickers approved by CERN.**
- **Engineering specification of amplifier performed for approval.**
-
- **Manufacturing of the ceramic parts started by "Thorium".**

FEL based on the induction linac LUI-3000

Project CLIC, Collaboration CERN = JINR =- Institute of Applied Physics ,Nizhny Novgorod

FEL at the induction linac LUI-3000

RF detector with the set of waveguide cut-off filters



The electron beam bunching registered in the visible light in the experiments with the FEL oscillator. The generation of the microwave radiation at the mode of HH type at the frequency of 30.7 GHz (9.77 mm); the FEL oscillator scheme.

The FEL radiation application: Study of "The thermoshock effect" in cavities (CLIC project)

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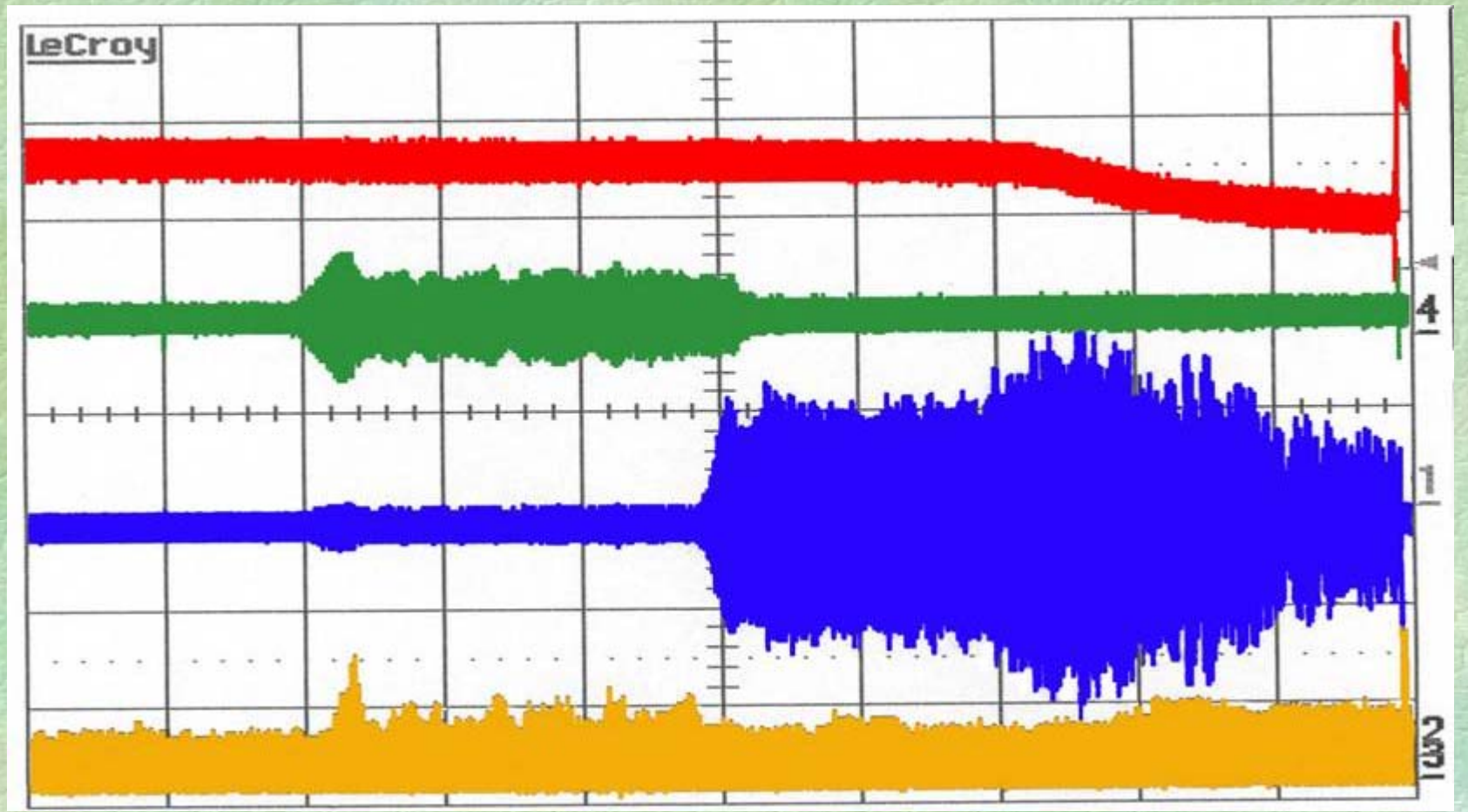
Development of proton beam instability in COSY during electron cooling, signals from PU electrodes



2 May 2002

Electron cooler for TerraWatt Accumulator

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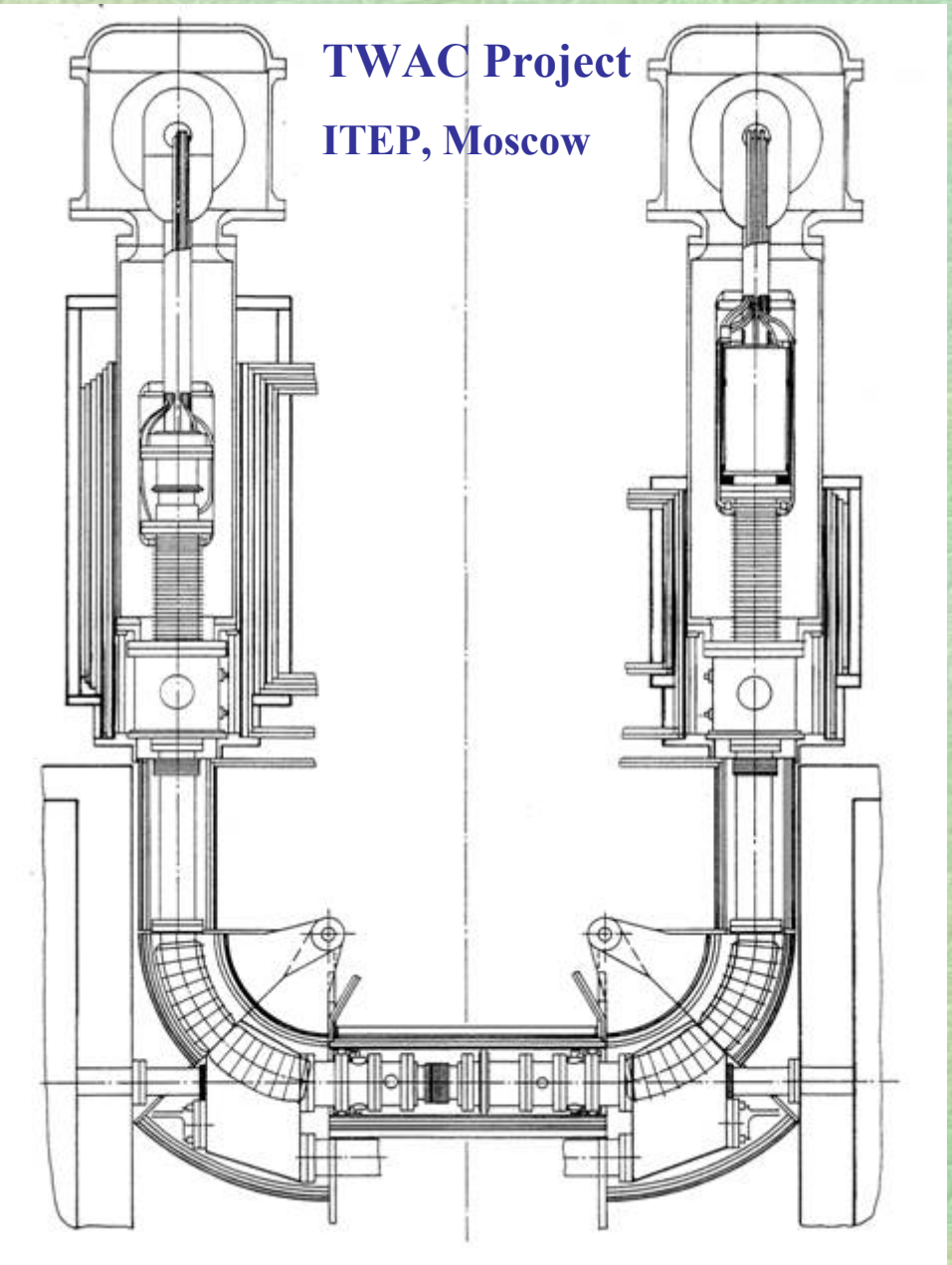

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Collaboration in the RI Beam Factory Project

(RIKEN, Japan)

Existing Facility:

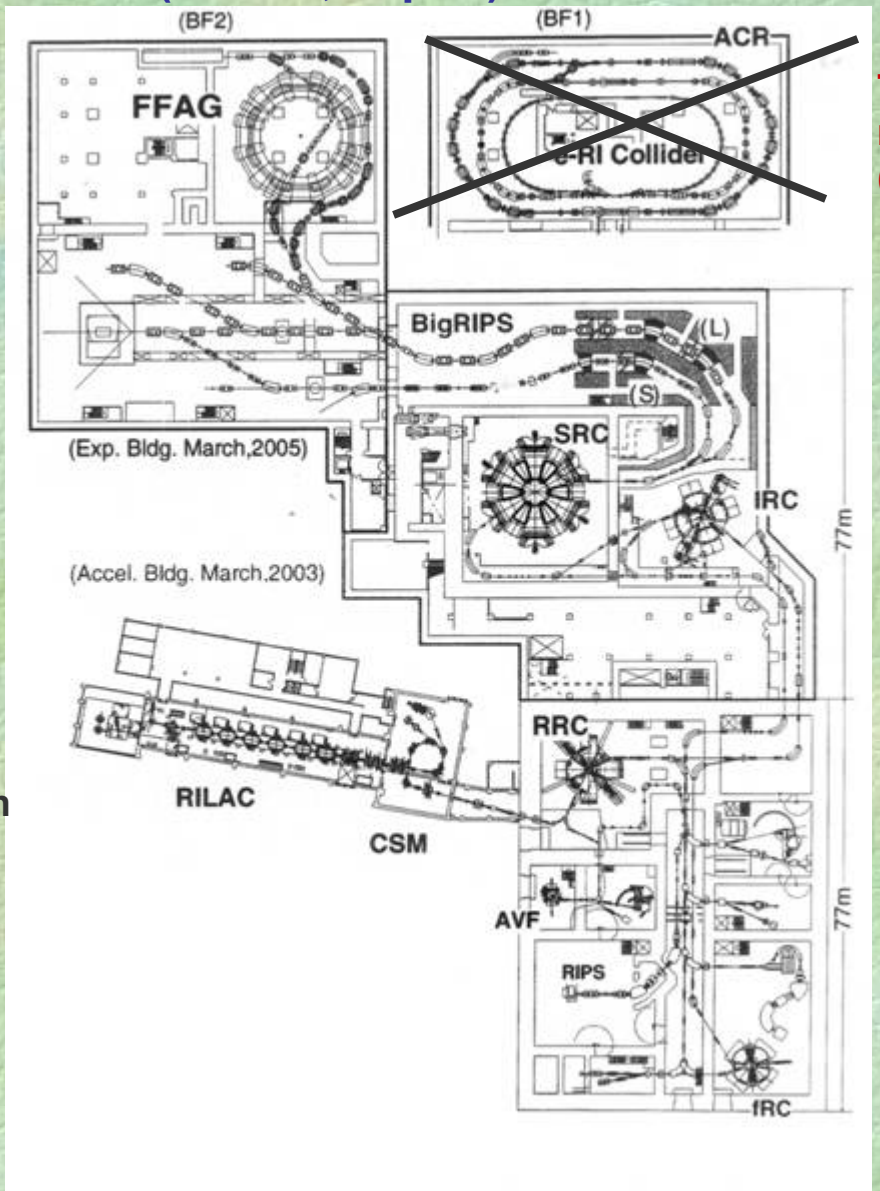
- RILAC: Frequency – variable Heavy-Ion Linac.
- CSM: Change State Multiplier.
- RRC: K540 MeV Ring Cyclotron.
- AVF: K70 MeV AVF Cyclotron.
- RIPS: Projectile Fragment Separator

RIBF Phase I:

- SRC: K2500 MeV Superconducting Ring Cyclotron
- IRC: K980 MeV Ring Cyclotron
- IRC: K%@) MeV Fixed-frequency Ring Cyclotron
- Big RIPS: Projectile Fragment Separator

RIBF Phase II:

- ACR: Accumulator Cooler Ring
- e-RI Collider: Electron RI Beam Collider



To be reconsidered (May 2002)

Theme 1018: Project: Research on Ion Sources

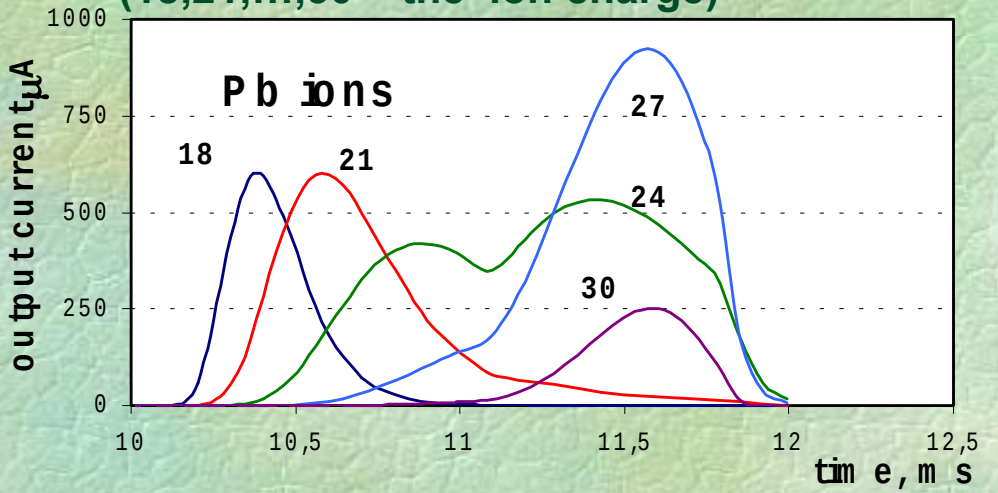
Laboratory for Particle Physics

1. Experimental studies of ECR sources - (Frankfurt University, RIKEN)

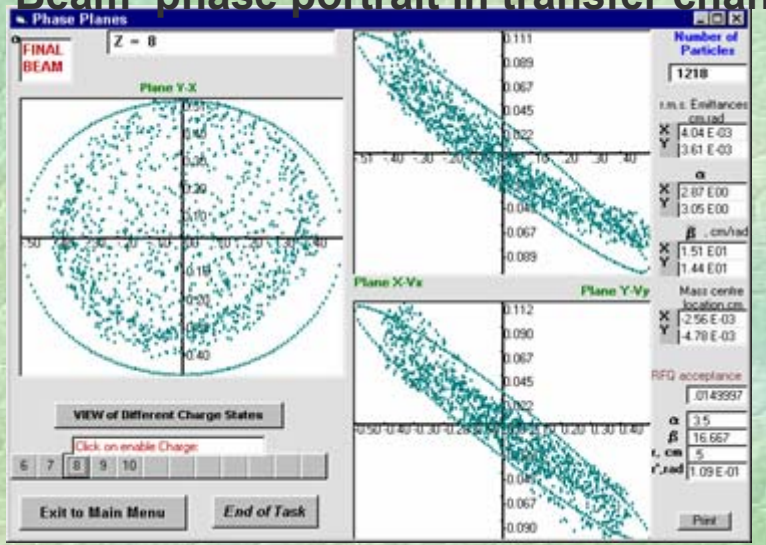
2. Laser injection into ECR sources – Flerov LNR (JINR), Frankfurt University, LNFN (Catania); RIKEN (Japan)

Goals: solid material loading
intensity increase

Numerical simulation of ECR source operation with plasma "emission" (18,21,…,30 – the ion charge)



Beam phase portrait in transfer channel



3. Particle-in-cell simulations – FLNR(JINR), RIKEN (Japan), Frankfurt and Dresden Universities:

- 2D, ion beam line optimization
- 3D, ECR plasma simulation (ISTC Project)

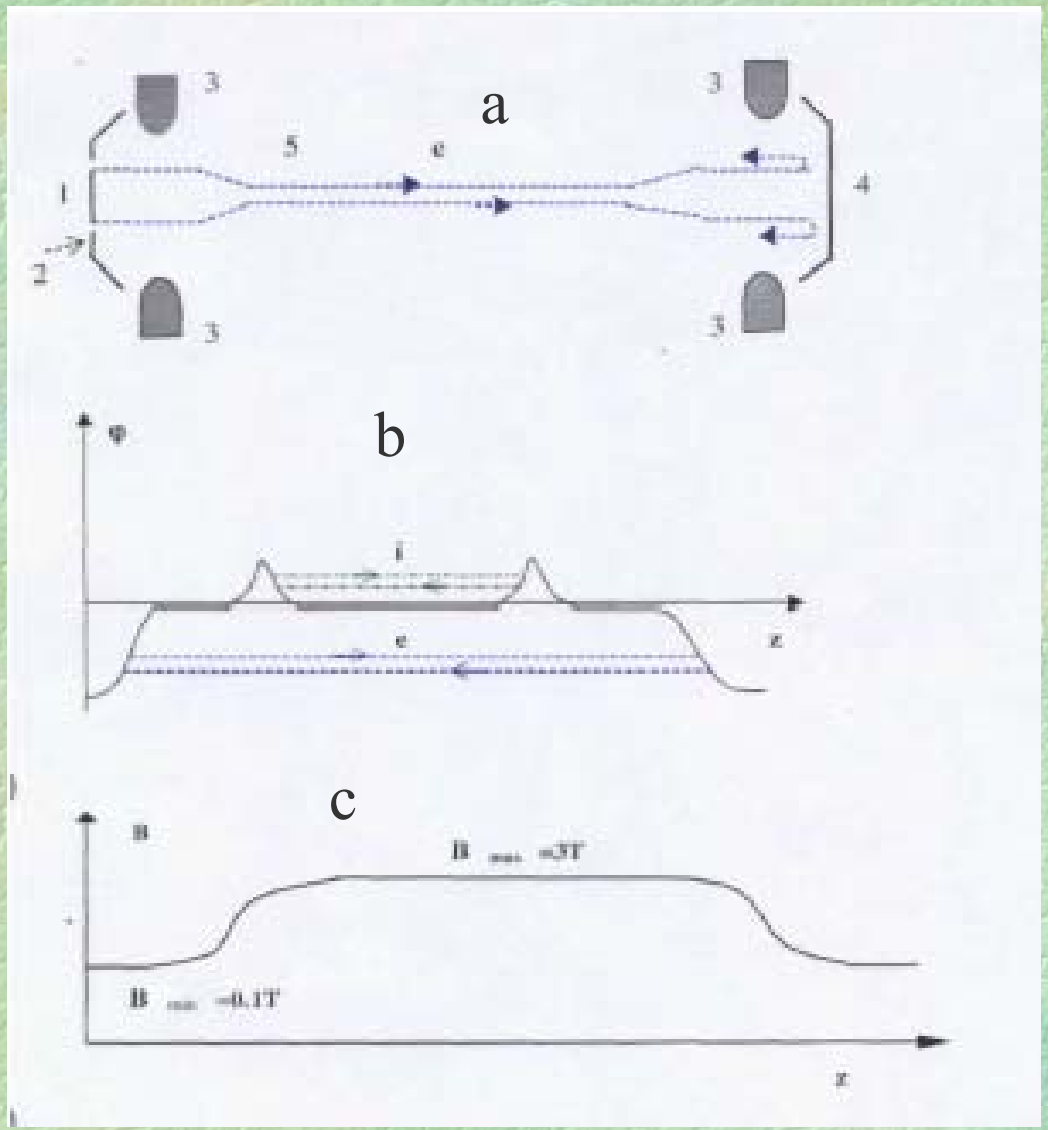
EBIS in reflection operation mode

Veksler-Baldin Laboratory of High Energies

a) The scheme of the electron beam generation in the reflection mode of EBIS operation: 1 - cathode, 2 - cathode electrode, 3 - anode, 4 - repeller (reflection electrode), 5 – typical electron trajectories;

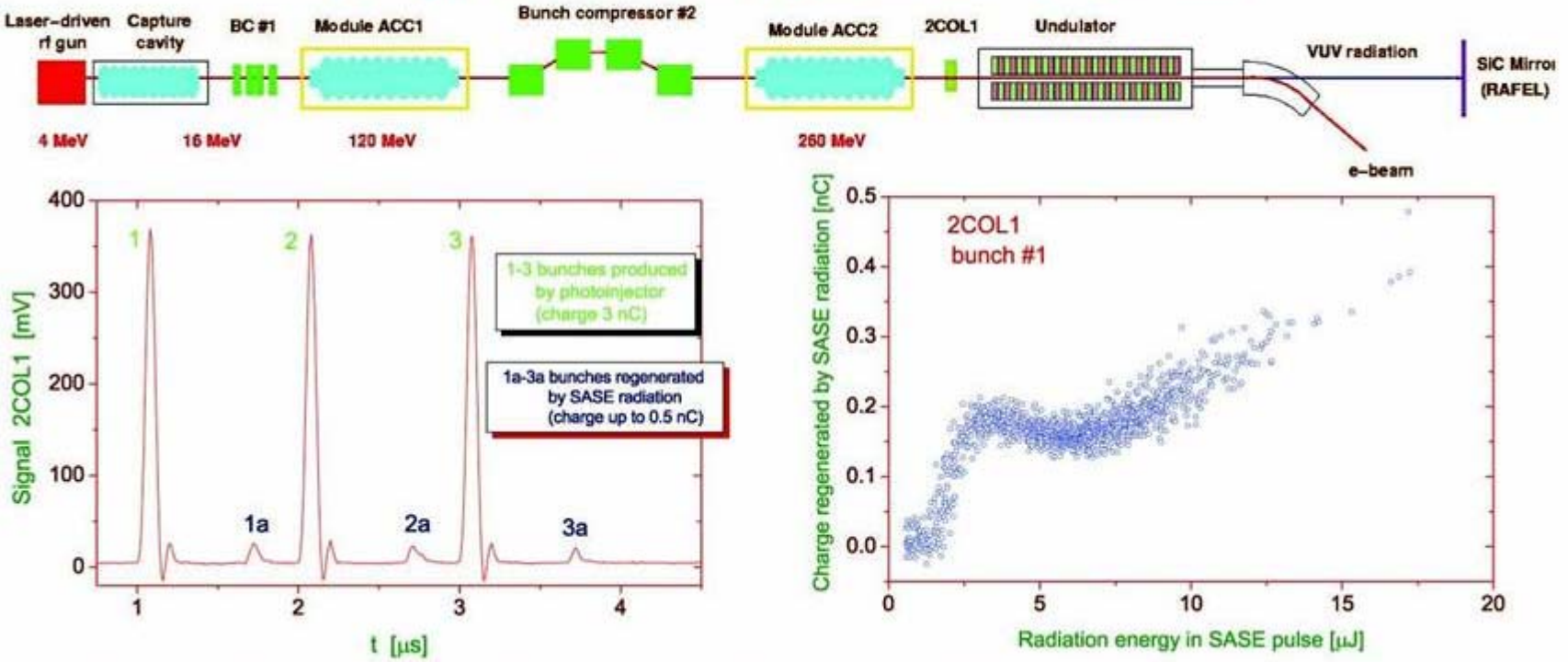
b) the potential distribution along the longitudinal axis;

c) the magnetic field distribution along the longitudinal axis.



LPP

Experiment on regeneration of electron bunches at the TTF accelerator using powerful VUV radiation from SASE FEL



- ✓ Primary electron bunches (charge 3nC) are produced by laser-driven rf gun
- ✓ During single pass of the undulator primary bunch produces powerful VUV radiation (95 nm)
- ✓ Radiation is reflected by plane SiC mirror and is directed back to the photocathode of rf gun
- ✓ Electron bunch produced by SASE radiation (charge up to 0.5 nC) is accelerated and detected by charge monitor 2COL1 installed at the entrance of the undulator
- ✓ Separation of regenerated and “parent” bunch is 650 ns (round-trip time between photocathode and mirror)

Conclusion

1. JINR research programs in accelerator physics & engineering *is very rich* !

2. The projects under realization at JINR have a modern level of quality and promise a good perspectives for the Institute.

3. High qualification of JINR accelerator specialists makes it possible for the JINR research groups to be involved in international collaborations and projects.

4. However, there exists an evident disadvantage:
manpower and resources aimed for realization of the programs are spread between the Laboratories and many tasks !

5. Having in view the nearest future (7 years plan) one has to concentrate all the efforts on the main goals of the JINR basic facilities development and the projects:

Nuclotron **IBR-2 refurbishment** **DRIBS**
IREN **LEPTA** **DELSY**
Phasotron (external injection)